Recommended Practice for Fixed Offshore Installations

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Section 1
General

1.1 Background

1.1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It now produces guidance for certification and verification during new construction and operation of fixed offshore installations.

1.1.2 Offshore services are delivered to clients by a number of other members, subsidiaries and affiliates of Lloyd's Register Group Ltd., including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

1.1.3 This Recommended Practice (RP) replaces the existing *Rules and Regulations for the Classification of Fixed Offshore Installations 1989 (amendments 2000)* and is applicable to offshore installations engaged in offshore operations including drilling, oil/gas production and storage, accommodation and other support functions. This RP is applicable to fixed offshore installations/platforms (a structure that is bottom founded and transfers all actions on it to the seabed) and that operate at a fixed geographic location for their entire service life. A typical offshore installation/platform consists of jacket, topside decks, piles and conductors; the RP does not apply to floating facilities to which other LR Rules are applicable.

1.2 Scope

1.2.1 This document defines a RP for managing facility integrity with respect to safety aspects for fixed offshore assets during the design and construction of an asset and continuing through the operational and decommissioning phases of an asset's lifecycle. The scope of this document includes requirements for design and survey which shall be controlled by establishing a formal data management system during construction, commissioning, operations (including risk-based techniques) and decommissioning of critical systems whilst integrating management of engineering change and survey of vendor supplied critical systems and equipment. This RP is applicable to fixed offshore installations:

(a) at which drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk is undertaken. It also applies to fixed offshore installations engaged in the control of hydrocarbon pipelines or subsea wellheads or utilised as part of a hydrocarbon pipeline system.

(b) at which offshore electrical substations/transformers, or control facilities are utilised in connection with offshore electrical power generation facilities, e.g. offshore windfarms, etc.

(c) that are either normally attended or normally unattended by personnel. It should be noted that dependent upon the extent of attendance at a fixed offshore installation considered to be a normally unattended (i.e. limited planned duration/occupancy of personnel attendance on an offshore installation), further special consideration at such an installation could be given.

1.2.2 A normally unattended installation (NUI) is an installation:

- which is not attended by any personnel for at least 9 months in a calendar year; and,
- is equipped only with emergency/temporary overnight accommodation facilities; and,
- has no planned routine daily personnel attendance.

Save that:

- attendance may take place for installation shutdowns, emergency repair, significant installation modification, commissioning or de-commissioning; or,

- if local statutory installations define NUI differently, then the local statutory definition will apply.

1.3 Audience

1.3.1 For organisations that will develop equipment or systems and require a means of third-party certification where no statutory requirements exist, the RP may be used for that purpose, and:

- Regulators may use and choose to adopt the RP for their purposes, be it setting it as a standard or adopting it in law.
- The document is intended to be used for project certification of installations, which also includes vendor equipment supplied to the project.
- Where RPs are applied to discreet systems they may be used in an equipment certification context.

1.4 Governance

1.4.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board'). The Board has appointed a Lloyd's Register Offshore Technical Committee and determined its powers, functions and duties. This RP has been reviewed by the Lloyd's Register Offshore Technical Committee for suitability in its application to the offshore environment.

1.5 Verification

1.5.1 LR will provide independent verification statements and reports describing compliance with the provisions of the RP. These may be expected to be used by duty holders and certifying authorities in the certification process for an installation.

1.6 Ethics

1.6.1 No LR Group employee is permitted under any circumstances to accept, directly or indirectly, from any person, firm or company with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value, or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

1.7 Non-payment of fees

1.7.1 LR has the power to withhold any certificate or report, in the event of non-payment of any fee to any member of the LR Group.

1.8 Limits of liability

1.8.1 When providing services, LR does not assess compliance with any standard other than the applicable codes and standards agreed in writing.

1.8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

1.8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as 'Lloyd's Register'. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

1.8.4 Except in the circumstances of *Ch 1, 1.8 Limits of liability 1.8.2*, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect consequential loss, damage or expense sustained by any person caused by any act, omission or error, or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

1.8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

1.9 Explanatory note

1.9.1 The inspection and survey of offshore structures is subject to the local laws and regulatory requirements as applicable. As such, elements within the RP may need to be modified to achieve local legal and regulatory compliance.

1.10 Use of shall and may

1.10.1 The use of the word 'shall' requires strict conformance with the requirements set forth within the document. The use of 'may' provides general guidance and options.

In the case of the use of may, in the general guidance and options, upon application to LR a submission may be made for alternatives to the RP guidance so long as they provide an equal or greater level of safety. In these instances, the solution is likely to be novel and may require qualification under such schemes as LR's 'Technology Qualification' programme.

Section 2
Abbreviations, definitions and references

2.1 Definitions

2.1.1 **Abnormal Level Earthquake (ALE)** – Intense earthquake of abnormal severity under the action of which the structure should not suffer complete loss of integrity.

2.1.2 **Accidental Limit State (ALS)** – Limit state related to the possibility of the structure to resist accidental loads and maintain integrity and performance.

2.1.3 **Accidental loads** – Rare occurrences of extreme environmental loads, fire, flooding, explosions, dropped objects, collisions, unintended pressure differences, etc.

2.1.4 **Admixture** – Material added during the mixing process of concrete, in relatively small quantities compared with the mass of cement, to modify the properties of fresh or hardened concrete.

2.1.5 **Aggregates** – Constituent material of concrete or grout added to increase volume, weight or durability of the material. Aggregates are the main constituent, with respect to both volume and weight, in a structural concrete mix.

2.1.6 **Cement** – Finely ground inorganic material which, when mixed with water, forms a paste that sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.

2.1.7 **Characteristic material strength** – The nominal value of material strength to be used in the determination of the design resistance. The characteristic material strength is normally based upon a five per cent fractile in the lower end of the distribution function for material strength.

2.1.8 **Characteristic value** – A representative value associated with a prescribed probability of not being unfavourably exceeded during some reference period.

2.1.9 **Concrete** – Material formed by mixing cement, coarse and fine aggregate, and water, with or without the incorporation of admixtures and additions, which develops its properties by hydration.

2.1.10 **Critical system** – A system, plant or equipment that has been identified to be critical to avoid negative consequences. Criticality could be determined by safety, environmental, business and reputational consequences**.**

2.1.11 **Deep dive** – An in-depth examination or analysis.

2.1.12 **Deformation loads** – Load effects on the structure caused by thermal effects, pre-stressing effects, creep/shrinkage effects, differential settlements/deformations, etc.

2.1.13 **Design life** – The duration to which the parameters used in structural design are related.

2.1.14 **Digital Twin** – A virtual model or representation of a physical process or plant that uses real world data.

2.1.15 **Discontinuity regions** – Area of disturbed flow of internal forces caused by the abrupt change in cross-sectional dimensions or concentrated loads.

2.1.16 **Ductility** – The property of a steel or concrete member to sustain large deformations without failure.

2.1.17 **Duty holder** – The Operator of the fixed installation responsible for operation and compliance with any regulations or specifications.

2.1.18 **Environmental loads** – Loads from wind, wave, tide, current, snow, ice and earthquake.

2.1.19 **Extreme Level Earthquake (ELE)** – Earthquake with a severity which the structure should sustain without major damage. When exposed to an ELE, a structure is supposed to retain its full capacity for all subsequent conditions.

2.1.20 **Fatigue** – Degradation of the material caused by cyclic loading.

2.1.21 **Fatigue analysis** – The type of analysis where the structure is assessed for the effect of cyclic loading.

2.1.22 **Fatigue Limit State (FLS)** – Limit state related to the possibility of failure due to the effect of cyclic loading.

2.1.23 **Finding** – Observation, anomaly or non-compliance with agreed specification or regulations.

2.1.24 **Finite element analysis** – Analysis method whereby a structure or a part thereof is subdivided into small elements of known or assumed behaviour, then analysed by numerical matrix methods to determine action effects, static or dynamic.

2.1.25 **Fixed structure** – Structure that is bottom founded and transfers all actions on it to the seabed.

2.1.26 **Grout** – Cementitious material that includes the following constituent materials: cement, water and often additions and admixtures. Appropriate fine aggregates may also be included.

2.1.27 **Hazard curve** – This is a linear log scale plot of platform base shear due to environmental loading for different environmental return periods.

2.1.28 **High strength concrete** – A concrete with compressive strength in excess of 65 MPa.

2.1.29 **Hindcast** – Simulated historical (metocean) data for a region developed through numerical modelling.

2.1.30 **In-place conditions** – The type of analysis is used to assess the strength of the structure in normal operation.

2.1.31 **Limit state** – A state beyond which the structure no longer satisfies the performance requirements.

2.1.32 **Live loads** – Loads which are related to the operation of the unit and can vary in magnitude, e.g. weight of furniture, stored goods and equipment, and loads associated with process, crane and helicopter operations.

2.1.33 **Local regulations** – Set of guidelines from a local government body that regulates oil and gas companies.

2.1.34 **Long-term distribution** – Probability distribution of a variable over a long timescale. The long timescale is usually measured in years and should be comparable to design service life of a structure.

2.1.35 **Management plan** – A document that will set out the method for control and management of the third-party scope of work for a new construction, major modification project or an existing fixed installation.

2.1.36 **Partial factor** – The partial factors are safety factors applied to actions (loads) and resistance (material properties), as part of load and resistance factor design.

2.1.37 **Punch list** – List of items that need to be addressed before a project can be deemed complete.

2.2 Abbreviations

2.2.1 **ALE** – Abnormal Level Earthquake

2.2.2 **ALS** – Accidental Limit State

2.2.3 **ALARP** – As low as reasonably practicable

2.2.4 **API** – American Petroleum Institute

2.2.5 **CAA** – Civil Aviation Authority

2.2.6 **C3A** – Tricalcium aluminate

2.2.7 **CO2** – Carbon dioxide

2.2.8 **CP** – Cathodic protection

2.2.9 **DFT** – Dry film thickness

2.2.10 **ELE** – Extreme Level Earthquake

2.2.11 **EN** – European Norm

2.2.12 **FLS** – Fatigue Limit State

2.2.13 **GGBFS** – Ground granulated blast furnace slag

2.2.14 **GNSS** – Global Navigation Satellite System

2.2.15 **ICCP** – Impressed current cathodic protection

2.2.16 **IOGP** – International Association of Oil and Gas Producers

2.2.17 **IEC** – International Electrotechnical Commission

2.2.18 **IMCA** – International Marine Contractors Association

2.2.19 **IMO** – International Maritime Organization

2.2.20 **IMR** – Inspect, Manage, Remediate

2.2.21 **ISO** – International Standards Organization

2.2.22 **ISSMGE** – International Society for Soil Mechanics and Geotechnical Engineering

2.2.23 **LAT** – Lowest Astronomical Tide

2.2.24 **LNG** – Liquid Natural Gas

2.2.25 **LR** – Lloyd's Register

2.2.26 **MHWS** - Mean High Water Springs

2.2.27 **NDE** – Non-Destructive Examination

2.2.28 **NFPA** – National Fire Protection Association

2.2.29 **OPC** – Ordinary Portland Cement

2.2.30 **PFA** – Pulverised fuel ash

2.2.31 **RITs** – Remote Inspection Techniques

2.2.32 **RP** – Recommended Practice

2.2.33 **SIL** - Safety Integrity Level

2.2.34 **SLS** – Serviceability Limit State

2.2.35 **S-N curves** – Curves specifying fatigue life

2.2.36 **SO2** – Sulphur dioxide

2.2.37 **SUT** – Society for Underwater Technology

2.2.38 **ULS** – Ultimate Limit State

2.2.39 **USBL** – Ultra-short baseline

2.3 Recognised Codes and Standards

2.3.1 The Codes and Standards detailed in this chapter are recognised by LR in connection with the design, certification and verification of the offshore installation as appropriate.

2.3.2 These Codes and Standards are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

2.3.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR:

- AISC 360-10,*Specification for Structural Steel Buildings*
- API RP 14B, *Recommended Practice for Design, Installation, Operation, Test, and Redress of Subsurface Safety Valve Systems.*
- API RP 14C, *Recommended Practice for Analysis, Design, Installation, and Testing of Safety Systems for Offshore Production Facilities.*
- API RP 14E, *Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems.*
- API RP 14J, *Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities.*
- API RP 2A-WSD, *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design.*
- API RP 2D, *Recommended Practice for Operation and Maintenance of Offshore Cranes.*

- API RP 2GEO*, Geotechnical and Foundation Design Considerations.*
- API RP 2SIM, *Structural Integrity Management of Fixed Offshore Structures.*
- API RP 2TOP, *Topsides Structure.*
- API RP 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2.*
- API RP 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities, Classed as Class I, Zones 0, 1 and 2.*
- API RP 7C-11F/BS EN 1834-1, *Installation, Maintenance, and Operation of Internal-Combustion Engines.*
- API SPEC 17D / ISO 13628-4, *Design and Operation of Subsea Production Systems – Subsea Wellhead and Tree Equipment.*
- API SPEC 17D, *Design and operation of subsea production systems.*
- API SPEC 6A & ISO 10423, *Wellhead and Christmas Tree: Equipment.*
- API SPEC 6A/ISO 10423, *Specification for Wellhead and Christmas Tree Equipment.*
- API STD 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries.*
- API STD 616, *Gas Turbines for the Petroleum, Chemical, and Gas Industry Services.*
- API STD 617, *Axial and Centrifugal Compressors and Expander compressors.*
- API STD 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*.
- API STD 671, *Special-purpose Couplings for Petroleum, Chemical, and Gas Industry Services.*
- API STD 672, *Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services.*
- API STD 674, *Positive Displacement Pumps—Reciprocating.*
- API STD 6AV2, *Installation, Maintenance and Repair of Surface Safety Valves and Underwater Safety Valves Offshore.*
- ASME B31.3, *Process Piping.*
- ASTM D4285, Standard Test Method for Indicating Oil or Water in Compressed Air
- ASTM E337, *Standard Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures).*
- BS 476-7, *Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products.*
- BS 7910, *Guide to methods for assessing the acceptability of flaws in metallic structures*.
- BS EN 10204, *Metallic products – Types of inspection documents.*
- BS EN 12495, *Cathodic protection for fixed steel offshore structures.*
- BS EN 13509, *Cathodic protection measurement techniques.*
- BS EN 1993-1-1:2005, *Eurocode 3, Design of steel structures — General rules and rules for buildings.*
- BS EN 1993-1-10, *Eurocode 3, Design of steel structures. Material toughness and through-thickness properties*.
- BS EN 50522, *Earthing of power installations exceeding 1 kV a.c*.
- BS EN 13852-1, *Offshore cranes – Part 1: General-purpose offshore cranes*
- BS EN 13852-3, *Offshore cranes – Part 3: Light offshore cranes*
- BS EN IEC 60079, *Explosive atmospheres* series.
- BS EN ISO 12944-6, *Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Laboratory performance test methods.*
- BS EN ISO 8501-1, *Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*
- BS EN ISO 8502-3, *Preparation of steel substrates before application of paints and related products. Tests for the assessment of surface cleanliness. Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method).*
- BS IEC 60092-502, *Electrical installation in ships. Tankers – Special features.*
- BS IEC 61892-7, *Mobile and fixed offshore units. Electrical installations. Hazardous areas.*
- CAP 437 Standards for Offshore Helicopter Landing Areas
- CAA Paper 2008/03 Helideck Design Considerations – Environmental Effects
- EI 15, *EI Model code of safe practice part 15: Area Classification for Installations handling Flammable Fluids.*
- ICAO Annex 14 Aerodromes Volume II Heliports
- IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES).*

- IEC 61511, *Functional safety – Safety instrumented systems for the process industry sector.*
- IEC 61892, *Mobile and fixed offshore units – Electrical installations.*
- IMCA S 015 Guidelines for GNSS positioning in the oil and gas industry, February 2021.
- IMCA S 017 Guidance on vessel USBL systems for use in offshore survey, positioning and DP operations, March 2017.
- IMO Code on Alerts and Indicators.
- IMO Fire Safety System (FSS) Code.
- IMO International Life-saving Appliance (LSA) Code
- ISO 10418, *Petroleum and natural gas industries – Offshore production installations – Process safety systems.*
- ISO 12478-1, *Cranes – Maintenance manual – Part 1: General.*
- ISO 12482-1, *Cranes – Condition monitoring – Part 1: General.*
- ISO 13702, *Petroleum and natural gas industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines.*
- ISO 13703, *Petroleum and natural gas industries – Design and installation of piping systems on offshore production platforms.*
- ISO 14692, *Petroleum and natural gas industries – Glass-reinforced plastics (GRP) piping – Part 1: Vocabulary, symbols, applications and materials.*
- ISO 15138, *Petroleum and natural gas industries – Offshore production installations – Heating, ventilation and air-conditioning.*
- ISO 15540, *Ships and marine technology – Fire resistance of hose assemblies – Test methods.*
- ISO 15541, *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench.*
- ISO 15649, *Petroleum and natural gas industries – Piping.*
- ISO 19900, *Petroleum and natural gas industries – General requirements for offshore structures.*
- ISO 19901-1, *Petroleum and natural gas industries – Specific requirements for offshore structures – Metocean design and operating considerations.*
- ISO 19901-2, *Petroleum and natural gas industries – Specific requirements for offshore structures – Seismic design procedures and criteria.*
- ISO 19901-3, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 3: Topsides structure.*
- ISO 19901-4, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*
- ISO 19901-8, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 8: Marine soil investigations*
- ISO 19901-10, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 10: Marine geophysical investigations*
- ISO 19902, *Petroleum and natural gas industries – Fixed steel offshore structures.*
- ISO 19903, *Petroleum and natural gas industries – Fixed concrete offshore structures.*
- ISO 19906, *Petroleum and natural gas industries – Arctic offshore structures.*
- ISO 19921, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.*
- ISO 19922, *Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.*
- ISO 21789, *Gas turbine applications – Safety.*
- ISO 3834, *All Parts, Quality requirements for fusion welding of metallic materials.*
- ISO 4309, *Cranes – Wire ropes – Care and Maintenance, Inspection and Discard*
- ISO 9927-1, *Cranes – Inspections – Part 1: General.*
- *LR Code for Lifting Appliances in a Marine Environment*
- *LR Guidance Notes for Offshore Wind Farm Project Certification.*
- *LR Guidance Notes for Risk Based Analysis: Collisions*
- *LR Rules and Regulations for the Classification of Offshore Units.*
- *LR Rules and Regulations for the Classification of Ships.*
- *LR Rules for the Manufacture, Testing and Certification of Materials.*
- MODU Code 2009, *Code for the Construction and Equipment of Mobile Offshore Drilling Units.*

- NACE SP0287, *Field Measurement of Surface Profile of Abrasive Blast-Cleaned Steel Surfaces Using a Replica Tape.*
- NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam.*
- NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*
- NFPA 17, *Standard for Dry Chemical Extinguishing Systems.*
- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection.*
- NFPA 70, *National Electrical Code.*
- PD 6695-1-10, *Recommendations for the design of structures to BS EN 1993-1-10.*
- SUT, *Guidance Notes for the Planning and Execution of Geophysical and Geotechnical Ground Investigations for Offshore Renewable Energy Developments*, Society for Underwater Technology, Update to be published 2021.

2.4 Reference papers

2.4.1 The following technical papers are also referred to in this RP:

- Jeanjean, P., Gavin, K., Gilbert, R., Haavik, J.B., Morgan, N. (2020). *A new 'Unified' CPT-based axial pile capacity design method for driven piles in sand*. In Frontiers in Offshore Geotechnics IV, Austin, TX.
- Lehane et al. (2021). *CPT-Based Axial Pile Capacity Design Method for Driven Piles in Clay*.
- Unified CPT Method in Sands (Lehane et al. 2020) and the Unified CPT Method in Clays (Lehane et al. 2021).

■ *Section 3*
New construction (including fabrication, installation and commissioning)

3.1 Scope

3.1.1 This section includes requirements for survey during construction and commissioning of critical systems and survey of vendor supplied critical systems and equipment.

3.2 Management plan

3.2.1 For new construction of installations under third-party survey, the work shall be set out and governed by management plans and inspection and test plans.

3.2.2 This will be a live document to be amended where necessary throughout the project. This document will set out the method for control and management of the third-party scope of work for a new construction project of an offshore installation and will provide the overall governance process. The management plan shall include an execution strategy and details of how supply of the agreed deliverables is achieved.

3.3 Inspection and test plan

3.3.1 An inspection and test plan should be prepared for the construction, installation and commissioning phases of the new installation. The third-party scope should be agreed and detailed in work instructions in line with established codes and standards (e.g. ASME and ISO) or client procedures. Sample sizes of equipment to be surveyed should also be agreed. Compliance with local regulatory bodies should be checked and aligned prior to implementation; note that this is a requirement in some jurisdictions and may require locally registered engineers to the jurisdiction to undertake the work.

3.3.2 Third-party scope may include:

- Review of construction work packs and testing records for materials, welding and NDT, on site and at vendor workshops;
- Witnessing and examining the fabrication/construction against approved drawings and specification;
- Review of the equipment test and commissioning records;
- Witnessing commissioning and function testing of critical equipment;
- Review of punch-list items and any deviations from design/specification;
- Audit of engineering contractor's Quality Assurance and Quality Control.

3.4 General comments for survey/Survey consideration

3.4.1 New installations are to be built under survey. From the commencement of work until the completion of the installation, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the

approved plans and documentation. Any items found not to be in accordance with the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.4.2 Methods of survey and inspection for construction which formally include procedures involving a recognised approved quality system shall be considered.

3.4.3 Copies of approved plans (showing the structure as built), essential certificates and records, the Operations Manual and other instruction manuals are to be readily available for use when required by the attending Surveyors.

3.4.4 When remote and/or automatic control equipment, alarms and safeguards are fitted to the machinery, drilling/process plant and riser systems, the equipment is to be arranged, installed and tested in accordance with the basis of design.

3.4.5 Vendor equipment surveys should be carried out where equipment is to be part of a critical system. The level of third-party involvement should be determined based on safety-critical criticality of the equipment in addition to any specific operational requirements.

3.5 Operations handover

3.5.1 Prior to the operational phase ensure that a suitable maintenance management process is in place, operational procedures have been developed and a robust management of change process is in place.

3.5.2 All punch-list items including any design and construction comments should be closed where practicable or an agreed plan for monitoring and close out should be agreed.

■ *Section 4*
Existing installations

4.1 Scope

4.1.1 This section includes requirements for survey during operations and decommissioning of critical systems whilst integrating management of engineering change and survey of vendor supplied critical systems and equipment.

4.2 Management plan

4.2.1 The management plan is a live document for agreeing and recording essential details of contracts and should be configured to suit the specific contract requirements.

4.2.2 The purpose of the management plan is to detail the contract-specific scope along with an execution strategy for supply of the agreed deliverables. It defines what the contract is intended to achieve with success criteria, defines how the objectives are going to be met and defines personnel responsibilities for achievement of the contract aims. The document will set the context, governance and reporting requirements and describes the controls that will be in place to manage the contract successfully.

4.2.3 Further, the management plan outlines the resources (financial, human and systems) required by the contract. The plan includes aspects of the cost, schedule, deliverables and communications that are agreed.

4.3 Communications plan

4.3.1 Implement a robust reporting and communications plan to ensure the Operator is always aware of the status of survey. The communications plan is to be defined and agreed at the start of the project. The plan should be maintained and remains live and will be subject to change.

4.4 Reporting

4.4.1 Timely, accurate and factual reporting is essential to work processes. Completion of the work scope should be detailed in survey reports. Reports should contain details of survey tasks completed, sample sizes, positive results, and findings (any observations or anomalies), and should clearly state suitability of critical equipment surveyed. Findings should be closed by identifying and fixing the root cause, which will aid continual improvement of the process.

4.5 Escalation levels

4.5.1 The agreed escalation levels describe how long findings should remain without progress or resolution before they are formally raised to a more senior level to resolve. The intention is to ensure that safety items/observations are formally closed. At a project level with multiple large contracts, a project sponsor group should be formed from senior members of the contractor parties to provide a means of issue resolution in a timely manner.

4.6 Survey and inspection management system

4.6.1 Software may be used that can manage ongoing survey, inspection and reporting suitability of the operational phase of offshore installations. This includes findings management, survey planning and reporting, and management of change.

4.7 Planning

4.7.1 A high-level plan for surveys should be arranged and agreed. Suitable dates and timescales should be agreed, with the aim of completing the annual survey scope.

4.7.2 A detailed scope for each survey should be created and include a list of critical systems to be surveyed with a list of tasks.

4.7.3 Typical offshore tasks include:

- Witnessing function testing and assurance activities of critical systems.
- General visual inspection of the condition of critical systems.
- Auditing assurance processes for critical systems.

4.7.4 Typical onshore tasks include:

- Review of maintenance and inspection strategy/procedure documents for suitability to maintain critical systems.
- Audit of integrity management strategy for structures, pipelines and critical process systems to ensure close out of anomalies.
- Review of maintenance and inspection records of critical systems.
- Review of anomalies, defects, temporary repairs and maintenance/inspection deferrals to ensure they are appropriately managed to ensure suitability of critical systems.

4.8 Management of change

4.8.1 Ensure that when any changes or repairs are made to critical systems that they remain suitable (in compliance with the relevant standards) and effective, and that safety is not compromised. An effective change management process will improve safety levels, regulatory compliance and environmental performance, and will preserve company reputation and support operations through to the end of installation life. Inspection at vendor works for management of change to ensure vendors have an appropriate process in place and that vendor packages achieve the required standard of the critical systems.

4.9 Continuity of service

4.9.1 An annual statement of suitability of the critical systems should be prepared by the third party to provide an overall status of the offshore installation.

■ *Section 5*
Guidelines for third-party survey using risk assessment techniques to determine ongoing suitability

5.1 Risk-based surveys

5.1.1 Risk-based assessment techniques can be agreed based on historical data, trending and criticality of equipment and systems coupled with advances in technology enabling remote type surveys.

5.1.2 Risk-based assessment techniques are an alternative to the traditional periodical survey scheme. They are applied by putting into effect a risk-based assessment plan approved by the third party, with the purpose of focusing survey time on the higher risk and more critical systems. Risk-based approaches should be project specific and not generic.

5.1.3 The first stage is to decide if risk-based assessment techniques can be applied to the relevant installation. Existing installations require sufficient technical knowledge and historical data to develop an appropriate risk-based assessment plan. For new constructions, risk-based assessment techniques should be considered in the design phase of the project in order to ensure appropriate information is available. The cost-effectiveness of applying risk-based assessment techniques to the installation should also be assessed, along with any proposed technology and required infrastructure to support it.

5.1.4 For installations new to the third-party survey, the operational history, inspection data and survey history may not be available. In such cases, data from a fabrication analysis, corrosion studies and previous surveys may be used. However, where

input data is limited, a more conservative approach to risk-based assessment may be taken or it may be decided that risk-based assessment is not suitable for the installation until sufficient data is built up. Established and credible industry knowledge including reliability data may also be utilised where installation-specific historical data is limited.

5.1.5 Appropriate and sufficient information (input data) on the current condition of the components is required from the outset for preparing and using an effective risk-based assessment. A combination of the below listed data may be used as a basis for the risk-based assessment.

- Current condition of the critical systems including damage and repair records;
- Design and modelling data of the critical systems;
- Facility operating/loading pattern(s) (e.g. fatigue analysis);
- Historical survey results and recommendations from existing survey reporting and planning software;
- Maintenance, inspection and failure records;
- Reliability records.

5.1.6 A risk-based assessment plan is a live and dynamic process that will need regular updates depending on all the new information becoming available such as survey results and inspection data. It is important to decide when the risk-based assessment plan should be updated. Every performed survey will provide new information. It is essential that the assurance process is proactive rather than reactive and reliability modelling will support development of a risk-based survey process. As a guide each survey should be followed by a discussion regarding the findings and whether they matched the expectations before the survey based on the risk-based plan. The plan should be reviewed annually to determine if it is meeting the requirements of the installation and whether the predictions of the plan are broadly in line with the installation's performance. Every five years the plan should be subject to an in-depth examination or analysis to assess its performance and continued suitability for the installation.

5.2 Remote type surveys/Digital Twins

5.2.1 In all instances non-conventional and digital type surveys must be assessed for compliance with local legal and regulatory requirements before implementation.

5.2.2 The extent of the activities that can be remote witnessed is developed through an understanding of the installation condition and will depend on the facilities and infrastructure, e.g. wireless communication, on site; therefore, proposals should be discussed and planned prior to implementation.

5.2.3 Digital Twins may be considered for some aspects of what may be regarded as inspection and survey activities subject to *Ch 1, 4.3 Communications plan 4.3.1*. Where this is allowed the services should meet the requirements in *Ch 1, 5.2 Remote type surveys/Digital Twins 5.2.3* to *Ch 1, 5.2 Remote type surveys/Digital Twins 5.2.7*.

5.2.4 Be part of an integrated plan such as Risk Based Inspection with the limitations of the technology recognised and incorporated within the plan.

5.2.5 Remote witness technology must demonstrate that it meets an industry accepted standard.

5.2.6 Where Digital Twins are employed it should be demonstrated that the software has been developed in accordance with a recognised standard.

5.2.7 Where dependency on operational decisions is made with respect to inspection and survey, the Digital Twin should be shown to meet the requirements of a digital compliance framework which assesses the viability of the Digital Twin from design through to in-service operation. A recognised alternative to this may be considered, subject to review and acceptance.

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Section 1
General requirements

1.1 Background

1.1.1 This Chapter gives the requirements for selection of materials for steel fixed structures.

1.1.2 This Chapter shall be applied as supplementary to those requirements specified in the Rules for the Manufacture, Testing and Certification of Materials, referenced in this document.

1.1.3 This Recommended Practice relates in general to the construction of steel fixed structures of welded construction, although consideration will be given to use of other materials. For concrete structures, *see Ch 5 Concrete Structures*.

1.1.4 The materials used for construction and repair of steel fixed structures are to be manufactured and tested in accordance with the Rules for the Manufacture, Testing and Certification of Materials. Classification aspects of the Rules for the Manufacture, Testing and Certification of Materials shall not apply to fixed steel structures subject to certification or verification. It is not mandatory to source materials from LR approved works. Material certification requirements will be as per *Ch 2, 1.1 Background 1.1.6*.

1.1.5 As an alternative, materials which comply with national or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of the Rules for the Manufacture, Testing and Certification of Materials or are approved for a specific design application. For further guidance on material selection, *see Ch 2, 2 Material selection*.

1.1.6 Materials certificates for special and primary steel structures should satisfy EN 10204 Type 3.2 certification level. EN 10204 Type 3.1 certification should be acceptable for steel structures of secondary category.

1.1.7 Proposals to select materials according to acceptance criteria different from those given in this Chapter will be given special consideration. Such proposals should be accompanied by definitions of the criteria used, and a justification of their applicability.

Section 2
Material selection

2.1 Basis of selection

2.1.1 Materials are to be selected in accordance with the requirements of the design in respect of static strength, fatigue strength, fracture resistance and corrosion resistance as appropriate.

2.1.2 Adequate static strength is to be confirmed by specifying yield stress, tensile strength, reduction of area, and elongation.

2.1.3 Adequate fatigue strength is normally assured in the design process and by considering established fatigue data for constructional details in specified materials. It is not normally required to carry out fatigue tests as part of the materials specification.

2.1.4 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels are to be selected with a suitable level of notch toughness. The toughness class required is in general related to the structural category, design temperature and design thickness of the structural component. *See Table 2.2.1 Thickness limitations for structural steels*

for various application categories and design temperatures for use in welded construction including plates, bars, sections, forgings and castings.

2.1.5 For materials where the principal loads or welding stresses are perpendicular to the plate thickness, the requirements for through-thickness properties must be considered. The specific requirements for through-thickness testing and/or for low sulphur level should be either determined using EN 1993-1-10 or subject to the agreement of LR, or an alternative recognised National or International Standard.

2.1.6 The effects of corrosion from the offshore environment are to be considered. Detailed requirements in relation to corrosion protection of carbon and carbon-manganese steel structures are given in *Ch 6 Corrosion and Protection*.

2.1.7 For the sole purpose of determining material requirements, three structural categories are defined as follows:

(a) Special: Primary structural elements which are in way of critical load transfer points and stress concentrations (e.g. main nodes).

(b) Primary: Structural elements essential to the overall integrity of the installation (e.g. bracings).

(c) Secondary: Structural elements of minor importance, failure of which would be unlikely to affect the overall integrity of the installation (e.g. minor conductor framing and minor deck structure). Ancillary items such as stairs, handrails and walkways are excluded.

2.1.8 The above structural categorisation can be aligned with the structural design class approach of ISO 19902 as follows:

- DC 1: special;
- DC 2: primary;
- DC 3 and DC 4: secondary;
- DC 5: ancillary items.

2.1.9 A comprehensive list of structural components and their equivalent structural design classes are defined in ISO 19902 Annex D. For topsides structures the equivalent design classes are defined in ISO 19901-3. For other non-conventional structural components of fixed offshore structures refer to *Pt 4, Ch 2 Materials* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

2.1.10 The minimum design temperature (MDT) for the selection of grades of steel is to be the lowest daily mean temperature for the proposed location based on the 100-year average return period. It is to be rounded to the nearest 5°C below.

Table 2.2.1 Thickness limitations for structural steels for various application categories and design temperatures for use in welded construction including plates, bars, sections, forgings and castings

Structural category	Required steel grade, *see* Note 2	Maximum thickness permitted (mm) for various minimum design temperatures			
		0°C	–10°C	–20°C	–30°C
Secondary	A	30	20	12,5	X
	B	60	50	25	10
	D	100	100	80	50
	E	150	150	120	100
	AH	50	40	25	10
	DH	100	100	70	50
	EH	150	150	100	80
	FH	150	150	150	120
	AQ	50	40	25	10
	DQ	100	100	70	50
	EQ	150	150	120	80
	FQ	150	150	150	120

Primary	A	20	12,5	X	X
	B	25	25	12,5	X
	D	50	50	30	20
	E	100	100	65	40
	AH	25	25	12,5	X
	DH	50	50	30	20
	EH	120	100	65	40
	FH	150	150	150	100
	AQ	25	25	X	X
	DQ	50	50	30	20
	EQ	120	100	65	40
	FQ	150	150	150	100
Special	A	12,5	X	X	X
	B	15	12,5	X	X
	D	30	30	20	10
	E	100	75	35	30
	AH	20	12,5	X	X
	DH	30	30	12,5	10
	EH	100	75	35	25
	FH	150	100	80	50
	AQ	15	12,5	X	X
	DQ	30	30	12,5	10
	EQ	100	75	30	25
	FQ	150	100	80	60

Note 1. X indicates that the material is not permitted for that design temperature and structural category.

Note 2. Materials are to comply with the requirements of *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. Castings and forgings shall satisfy the same Charpy's V-notch requirements as the equivalent plate grades in this table.

Note 3. Q grades refer to quenched and tempered grades (*see Ch 3, 10 High strength steels for welded structures* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*).

Note 4. The thicknesses refer to as constructed thicknesses (e.g. design thickness plus any allowances such as corrosion allowance).

Note 5. Requirements for minimum design temperatures lower than –30oC will need special consideration, which may include the use of fracture mechanics assessments.

Note 6. Thicknesses greater than those shown in this Table may be used subject to special consideration and may include fracture mechanics assessment.

Note 7. The interpolation of thicknesses for intermediate temperatures may be considered.

Section 3
Fabrication

3.1 General

3.1.1 In general, the requirements for welding are given in *Ch 12 Welding Qualifications* and *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*. LR approved welding consumables will not be considered mandatory for this application.

3.2 Specific requirements for fixed offshore steel structures

3.2.1 In addition to *Ch 2, 3.1 General 3.1.1*, the requirements highlighted in *Ch 2, 3.2 Specific requirements for fixed offshore steel structures 3.2.1*, *Ch 2, 3.2 Specific requirements for fixed offshore steel structures 3.2.7* and *Ch 2, 4 Quality Assurance* should be applied.

3.2.2 For all steel structures, the impact test temperature and minimum absorbed energy for the weld and heat affected zone are to be the same as those specified for the base materials being welded as per *Table 2.2.1 Thickness limitations for structural steels for various application categories and design temperatures for use in welded construction including plates, bars, sections, forgings and castings*.

3.2.3 Fabrications where the weld throat thickness exceeds 65 mm are, in general, to be subjected to a post-weld heat treatment. Impact tests are required to be made on a specimen heat-treated in the same manner as the actual construction. The absorbed energy should be the same as specified for the base material; however, the test temperatures may be 10°C higher.

3.2.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on engineering criticality assessment by fracture mechanics using established procedures as defined in BS 7910 or an equivalent International Standard.

3.2.5 All NDE is to be performed in accordance with the requirements specified in *Ch 13, 2 Specific requirements for ship hull structure and machinery* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

3.2.6 The extent of NDE is to be specifically agreed with LR and shall as a minimum satisfy the extent of NDE in ISO 19902 based on the structural design class approach and the equivalent inspection categories. Equivalent structural design classes and inspection categories are summarised in ISO 19902 Annex D.

3.2.7 All other aspects of fabrication not covered by this Chapter should be governed by the requirements of ISO 19902.

Section 4
Quality Assurance

4.1 General

4.1.1 In general, the requirements for Quality Assurance and quality systems shall be in accordance with ISO 19902 based on structural exposure levels L1, L2 and L3 as defined in the standard.

4.1.2 In addition, all fabricators of special and primary structures should possess Quality Assurance systems endorsed by an independent third party satisfying the requirements of ISO 3834-2 as a minimum. Quality Assurance systems of fabricators who are only involved in the construction of secondary structures should only need to satisfy the requirements of ISO 3834-3.

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Section
1 **Environmental considerations**

2 **Geotechnical**

Section 1
Environmental considerations

1.1 Recognised codes and standards

1.1.1 Design metocean parameters such as waves, winds, current and water levels should be derived in accordance with ISO 19901-1. This Section of the Recommended Practice (RP) supplements, rather than replaces, the requirements of ISO 19901-1.

1.2 Metocean database

1.2.1 Design metocean parameters should be derived based on the site-specific database. The metocean database should include time stamped characterisation of the climate over a sufficiently long period of time. The time stamp is commonly at every one or three hours.

1.2.2 Where possible, the database should be of sufficiently long duration to encompass all the physical processes which can be encountered during the lifetime of the structure. Because the return period of key design parameters for fixed platforms is 100 years, given ISO 19901-1 recognition that metocean parameters can be estimated with some confidence with return periods of up to a factor of three beyond the length of the available data set, the duration of the database should ideally be 25 years or longer.

1.2.3 The database may be established either by site-specific measurements over a period of years or by numerical modelling (hindcasts) of historical events. If numerical simulations are used, the simulated results shall be calibrated (or verified) against appropriate measurements. In practice, both measured and hindcast data are often needed, because measured data covering a sufficiently long period of time is rarely available, whereas hindcast data, which can be available for longer periods of time, still requires some measured data for verification and calibration.

1.3 Tropical cyclone regions

1.3.1 Information on the types of storms typical to the region should be used to supplement available data. In tropical cyclone regions, when determining the appropriate environmental conditions it is important to separate storms of different types, such as, for example, monsoons and typhoons, before performing an extreme value analysis. Furthermore, it can be necessary to set operating limits for a particular structure for particular storm types and seasons.

1.4 Directionality

1.4.1 In some locations the environment is markedly directional. This can be due to topographic features which can provide fetch limitations on wave heights from particular directions, representative storm tracks, or tidal or general circulation currents, which can have predominant direction.

1.4.2 For design in such situations, different wave, wind and/or current magnitudes may be used for different approach directions, provided that sufficient reliable data are available to derive them. When directional data is used, it is important to ensure that the overall reliability of the structure is not compromised by the use of directional environmental conditions.

1.5 Extreme value extrapolation

1.5.1 Design of fixed offshore platforms requires design parameters at return periods which are significantly longer than the length of available metocean databases. Hence the design values are usually derived by fitting assumed distribution to available data points and extrapolating to required return periods.

1.5.2 A number of different methods are available for extreme value extrapolation. For example, a distribution function can be fitted to each time-stamp data point in the database (usually referred to as Initial Distribution Method – IDM) or to the data points which exceed a certain threshold (usually referred to as Peaks Over Threshold – POT method). Peaks Over Threshold method is generally considered superior as the extrapolation is based on independent storm events.

1.5.3 There are also a number of different distributions which can be used in extrapolation. According to ISO 19901-1 the most robust extreme estimates are obtained by finding the distribution that fits a subset of a reasonable number of the more extreme data points most closely, using an error-minimising algorithm (e.g. maximum likelihood method). Hence, a variety of

different techniques should be considered before deciding on an extreme value, e.g. the use of different thresholds, different distributions, annual maxima, Peaks Over Threshold (POT) and cumulative frequency distribution analyses.

1.6 Maximum wave height and wave crest values

1.6.1 The required long-term individual wave height or crest height should be established by convolution of long-term distributions derived from these data with a short-term distribution that accounts for the distribution of individual wave heights in a sea state.

1.7 Fatigue data

1.7.1 The minimum requirement for the fatigue assessment of a fixed structure during the in-place situation is an appropriate description of the site-specific wave environment during its design service life. This is ideally provided by scatter diagrams describing joint distribution of the significant wave height (Hs), a representative wave period (Tz or Tp) and the mean wave direction (θ). The scatter diagrams should cover either the full duration of the design service life or the duration of a typical year. If annual distributions are used, it is assumed that the conditions during the typical year repeat themselves each year during the design service life.

1.7.2 Where a deterministic fatigue assessment can be used for quasi-statically responding structures, the scatter diagram should provide joint distribution of the individual wave heights (H) and associated periods (T), and the mean wave direction (θ).

1.7.3 Where vortex-induced vibrations (VIV) due to currents in the in-place situation are important, the long-term marginal distribution of site-specific current speeds should also be determined.

1.7.4 For VIV due to wind action in the pre-service condition, the long-term marginal distribution of sustained wind speeds during the construction period should be made available.

1.7.5 For slender structural components above water (e.g. drilling derricks, flare towers), the long-term marginal distribution of sustained wind speeds should suffice for a fatigue assessment owing to excitation by both gust winds and vortex induced vibrations.

1.8 Water surface elevation for air gap assessment

1.8.1 Ideally, the air gap assessment should be based on long-term surface elevation statistics accounting for the joint probability of tide, surge height and crest heights to estimate the maximum surface elevation relative to the deck. In this case, a probability of non-exceedance close to the target failure rate of the structure may be used with no additional air gap allowance added.

1.8.2 When obtaining long-term surface elevation statistics is not practicable, the 10000-year water surface elevation can be estimated based on ISO 19902 equations A.6.3-1 and A.6.3-2. Equation A.6.3-1 assumes that the storm surge and abnormal wave crest are independent and do not occur at the same time, and thus represents the lower bound value. Equation A.6.3-2 assumes that storm surge and abnormal wave crest are fully correlated and occur at the same time, and thus represents the upper bound value. Whilst in most practical cases the actual value would be expected to lie somewhere between the lower and upper bound, equation A.6.3-2 should be used unless it is demonstrated through joint probability study of storm surges and wave crests that the lower value can be adopted.

1.8.3 The crest elevation estimates derived using measurements at a single point effectively only reflect the risk of exceedance at a single point. However, when the true area of exposure to wave crests is considered (i.e. the full platform-deck area), the probability of having the point estimate exceeded somewhere locally within the deck is higher than the probability of having it exceeded just at one point, since the potential crest encounter area is larger than one point. When the entire deck area is considered, a local crest height occurring somewhere in the deck area can exceed the point-estimated crest height by as much as 15 per cent for the same probability level. Such increase may be treated as a local effect only and it should be accounted for in the local design of exposed platform elements, as appropriate.

1.9 Snow and Ice loading

1.9.1 In regions with seasonal snow and ice cover, actions due to snow and ice shall also be considered. The recognised industry standard for determining ice and snow loads on offshore structures is ISO 19901-1. For design of Artic offshore structures please refer ISO 19906.

Section 2
Geotechnical

2.1 General foundation requirements

2.1.1 This Section relates specifically to the following foundation types of offshore fixed structures: driven tubular piles, drilled and grouted piles, gravity base shallow foundation and suction caissons. Other foundation types will be specially considered.

2.1.2 The foundation design shall be based upon the expected site and seabed conditions at the proposed location. The foundation shall be demonstrated to be acceptable for the location, taking into account capacity and stiffness requirements (vertical, horizontal, moment and torsion) with appropriate load and resistance factors and that it can be successfully installed.

2.1.3 The following information is to be submitted:

- Geotechnical and geophysical site investigation data shall be performed in accordance with ISO 19901-8 and ISO 19901-10 respectively.
- A ground model defining design parameters and conditions for the foundation concept.
- An assessment of any seabed features that may impact the structure location, including whether they might pose a hazard.
- A seismic hazard assessment to the required level of detail for the site and development in accordance with ISO 19901-2 or similar. A detailed probabilistic seismic hazard assessment shall be performed if appropriate.
- A seabed level change assessment (if appropriate).
- A foundation design basis defining applicable codes and standards, design methodology, scour philosophy, scour allowance(s), design tolerances, acceptance and performance criteria, and interfaces with other assets.
- Data, calculations and analysis supporting the design of the foundation.
- Foundation drawings including layout of the structure in relation to available site investigation data.
- Foundation installation records.

2.2 Foundation loads

2.2.1 Geotechnical design shall take account of the nature of the loading placed upon the foundations as defined by the structural analyses.

2.2.2 The effects of cyclic loading shall be accounted for within the foundation design.

2.3 Location control

2.3.1 Throughout the development of a fixed platform, sufficient and professional oversight shall be applied to the setup, configuration, verification and acceptance positioning systems where used to compute the real-time absolute positions of site investigation data and locations on the seabed.

2.3.2 Full consideration shall be made to ensure that current operations and procedures, together with all previous survey and site data information, reference a single and consistent geodetic datum in terms of spheroid, datum and projection.

2.3.3 Where surface positioning is undertaken using GNSS (Global Navigation Satellite System), operations should be undertaken in alignment with IMCA (International Marine Contractors Association)/S 015 (Oil and Gas Producers). Alongside tests and checks should be undertaken in port to verify system setup and achievable accuracy at the computational point (e.g. stern roller or crane location).

2.3.4 Where sub-surface positioning is undertaken using USBL systems, operations should be undertaken in alignment with IMCA S 017. Verification and offshore calibration operations may be required dependent upon installation tolerance.

2.4 General geotechnical requirements

2.4.1 The geotechnical design of foundations should follow the guidance within this RP and can be performed in accordance with industry recognised methods such as those contained within the latest revision of ISO 19902 and API RP2A WSD with respective geotechnical codes including ISO 19901-4 and API RP 2GEO or similar Internationally Recognised Standards.

2.4.2 Analysis of the foundation under design loading is to take account of the non-linear stress/strain behaviour of the foundation soils, stress history and cyclic loading effects on soil resistance.

2.4.3 The foundation design is to take account of any jack-up siting at a location (past, present or future). Jack-up spudcan interaction can affect all foundation types and may include, but not be limited to, the following factors:

- Spudcan penetration and interaction effects on the foundation including vertical and horizontal loading, possible degradation of foundation capacity and stiffness and transfer of load into the structure.
- Effect of spudcan interaction on other nearby assets or interfaces (e.g. subsea assets, pipelines, risers).
- Disturbance of soil around piles due to spudcan penetration, particularly where the spudcan is jetted in or out.
- Effect of depression remaining after spudcan removed, including possible subsequent increase in seabed erosion.
- Possible increase in seabed erosion due to altered current regime.

2.4.4 The foundation design should take account of other nearby assets such as platforms, conductors, pipelines, cables and subsea structures.

2.5 Scour and erosion

2.5.1 The influence of erosion of soils from around and beneath the foundation is to be taken into account in its design. Erosion due to the following causes is to be investigated:

- The effect of waves and currents passing over the seabed at velocities sufficient to dislodge and transport particles of bed materials (scour and sand waves).
- The relief of hydraulic pressures and pore water pressures built up under the foundation due to environmental loading, which may cause the removal of soil from beneath the foundation (sub-surface erosion or piping).

2.5.2 There are generally two main approaches to account for scour and erosion. The first is to provide scour protection such that the foundation will not be impacted by scour. The second approach is to include scour allowances within the design calculations.

2.5.3 As per ISO 19901-4, scour is generally considered to constitute global and local components and seabed level change. Where appropriate these parameters should be defined. Once these parameters are defined they should be considered within the definition of scour inspection frequency periods, acceptance criteria and trigger points for remedial action.

2.5.4 The potential for pumping scour as a result of structural movement or structural effects is to be considered and accounted for.

2.5.5 If scour protection is used then it should be considered that the scour protection itself may be subject to scour and that it may be necessary to account for winnowing effects of the underlying soil below the scour protection, thus degrading the ability of the scour protection to maintain foundation integrity. The use of a filter layer may be required to ensure the long-term integrity of scour protection.

2.5.6 If it is suited to the seabed conditions and foundation type, it is acceptable to use an observational approach to manage scour. Generally speaking, an observational approach should ensure that the stability or integrity of the structure is not affected and may consider the following:

- Implementation of a scour inspection plan, taking into account the allowable scour behaviour assumed in the design.
- Inspection frequency and scope may be determined or optimised once the scour climate local to a structure is understood on the basis of as-installed experience.
- Where scour exceeds the design allowance the impact of this should be assessed and appropriate action should be taken. This could include, but not be limited to, increased scour inspection frequency or remedial action including the placement of scour protection.
- Within any scour inspection plan, it should be ensured that remedial action can be taken before the stability or integrity of a structure is affected.

2.5.7 Any scour or erosion protection system laid on the seabed is to be designed such that it will permit free dissipation of pore water pressures that may be generated in the surface soil under cyclic loading conditions.

2.5.8 The methods proposed for the prevention of and/or protection against erosion are to be submitted for approval. Options for scour protection include skirts, rock dump, grout bags and frond mats.

2.5.9 The configuration and dimensions (lateral extent, thickness) of the scour protection should be defined to ensure the scour protection fulfils its purpose of protecting the foundation for the service life of the structure. The scour protection shall be designed to be suitable under all limit states that the structure will be subjected to in its expected life. This includes, but is not limited to, ULS, ALS, FLS and seismic conditions. Where scour protection may prove critical to structural integrity the inclusion of appropriate load and resistance factors may be required. If rock is to be used as a solution to prevent scour then the rock should be appropriately selected and designed. Guidance is available in the CIRIA manual and in general the following aspects should be considered:

- Bearing capacity and settlement (short term and long term).

- Filter stability and filter criteria.
- Response of rock under seismic events, including effects of liquefaction.
- Rock stability under wave and current loading.
- The degree of damage that is acceptable whilst ensuring the rock fulfils its intended purpose (e.g. no damage versus acceptable damage design).
- Scour of the scour protection.

2.6 Slope stability

2.6.1 Where the foundation is located on or near a slope, the influence of the slope on the foundation is to be considered.

2.6.2 The possibility of failure of the slope due to wave or earthquake loading is to be investigated.

2.6.3 The results of any calculations or tests are to be submitted.

2.7 Earthquake

2.7.1 Where appropriate, the influence of earthquake loading on the foundation is to be fully accounted for in the design in relation to the particular site conditions. This assessment is to consider the site response, potential for seismic liquefaction and any other aspects that may influence the foundation such as slope stability.

2.7.2 Where appropriate, the possibility of post-seismic induced settlement and its magnitude should be accounted for during foundation design/selection.

2.7.3 Seismic design and seismic criteria should be considered in accordance with the latest revision of ISO 19901-2.

2.8 Unconventional soil

2.8.1 The site investigation and subsequent design should take into account the presence of unconventional soils, such as those listed in ISO 19901-8. It should be recognised that design methods that have been developed and used for design of offshore foundations in conventional soils may not be applicable to unconventional soils and that further investigation and testing may be required. Foundation design for unconventional soils will require special consideration.

2.9 General site investigation requirements

2.9.1 The methods of investigation are to be adequate to give reliable information for design and should take account of, but not be limited to, the following:

- Nature and stability of the seabed.
- Geomorphology and engineering properties of the strata underlying the seabed.
- Seabed topography in sufficient detail for the type of foundation being installed.
- Presence of sand waves, ripples and other mobile seabed features.
- Surface deposits, rock outcrops and debris.
- Variations in soil conditions at the foundation locations.
- Stability of sloping seabeds and other geohazards.
- Natural eruptions and erosion of the seabed due to emissions of gas, mud, fresh-water springs, etc.
- Presence of shallow gas.
- Other seabed infrastructure.
- Obstructions (artificial or otherwise).

2.9.2 The extent of investigations is to be sufficient in area, depth and detail to adequately cover the foundation and fixed structure design. This should take account of the following:

- Engineering requirements of the foundation and structure during construction and throughout the life of the structure.
- The complexity of the site and the anticipated seabed soil conditions to be encountered at the foundation locations.

2.9.3 Where a seabed feature is identified it should be assessed to determine whether it may become a hazard that affects the installation of the foundation or performance of the structure during its life. This should take into account the status of the feature measured at the time of survey and a prediction of any changes that may occur. Where a feature may pose a hazard it shall be assessed what action is required to manage it – for example, avoidance, monitoring, removal, mitigation.

2.9.4 In general, a site investigation is to consist of the following phases where appropriate:

- Desk study giving an initial ground model for the site.
- Geophysical site investigation.

- Geotechnical site investigation.
- Integration of geophysical and geotechnical data into a ground model.
- Determination of design parameters.

2.9.5 The desk study is to be performed prior to commencing other forms of site investigation. In offshore areas where detailed geological data already exist, this information is to be obtained and used to aid determination of the scope and method of site survey.

2.9.6 The desk study should also consider other foundations or structures that have been installed nearby and take account of information such as installation records or scour inspection reports.

2.9.7 Where necessary, site investigation phases are to be updated or repeated to ensure sufficient data is available for foundation design.

2.9.8 Further discussion on the process of site investigation and ground modelling is given in the OSIG renewables guidelines.

2.10 Geophysical site investigation

2.10.1 The surrounding geology and seabed conditions should be understood as required by ISO 19900. In the absence of a geophysical site investigation standard published by ISO, other good industry practice such as that published by the ISSMGE is to be taken into account when planning and implementing geophysical surveys. In addition, the guidelines on site investigation published by the Society for Underwater Technology provide useful information on planning and implementing a site investigation (SUT 2021).

2.10.2 The geophysical survey is generally to be performed over an area centred on the proposed location. The number and spacing of survey lines are to be appropriate for the site characteristics and type of foundation.

2.11 Geotechnical site investigation

2.11.1 The geotechnical site investigation should be performed in accordance with the requirements of ISO 19901-8. Geotechnical site investigation data is considered to comprise of sample data and associated laboratory testing and in situ test data that has been appropriately interpreted.

2.11.2 Geotechnical site investigation data is generally required at each structure location and the geotechnical data shall be sufficient to characterise each soil strata found across the site and provide input required for structural design. In some situations, more than one geotechnical investigation location may be required at a structure – for example, for large structures, complex soil conditions, or where the foundation is sensitive to uncertainties in soils data. Where site conditions are geotechnically uniform, a reduced number of geotechnical investigation locations may be justified. Such a reduction in geotechnical site investigation data is to be supported by proper integration of the geophysical and geotechnical data and a ground model.

2.11.3 Geotechnical site investigation and interpretation of a ground model should extend to a depth greater than the maximum anticipated depth of influence of the foundation.

2.11.4 When planning a site investigation, and selecting equipment, consideration should be given to issues that may affect the likely foundation type(s). For example, attention should be given to identifying any thin weak strata which may be critical to sliding capacity of a gravity base, but of relatively little significance to the design of friction piles.

2.11.5 The depth accuracy class, defined according to ISO 19901-8, should be selected to be appropriate for the foundation type. Some foundation types, such as a skirted gravity base, may be particularly sensitive to differences in depth of soil strata. In general, this should mean that a depth accuracy class of Z3, or better (i.e. Z1 or Z2), shall apply.

2.11.6 The sample class, as described in ISO 19901-8, should be appropriate for the foundation type and design requirements. In general, this should mean Class 3 samples, or better (i.e. Class 1 or Class 2), are obtained.

2.12 *In situ* testing

2.12.1 *In situ* testing is to be performed in accordance with ISO 19901-8.

2.12.2 For *in situ* tests (such as cone penetration tests or field vane tests) the Application Class is to be determined based on the foundation type and site conditions anticipated from the desk study.

2.13 Interpretation of site investigation

2.13.1 The results of the geotechnical investigation are to be interpreted and presented to allow understanding of soil and seabed conditions across the site and to provide input for design of the structure and foundations.

2.14 Unconventional soils

2.14.1 Site investigation in unconventional soils, or rocks, will require agreement with LR in advance.

2.15 General installation requirements

2.15.1 Details of the proposed foundation installation are to be submitted.

2.15.2 Surveys of the seabed are to be performed at the proposed structure location immediately prior to installation. The survey should provide confirmation that the foundation location and immediate surrounding area are free of any other seabed obstacles or obstructions that may have appeared in the period since the geophysical survey was performed.

2.15.3 Design installation tolerances shall be included in the installation philosophy and where tolerances are not met further confirmation of foundation suitability should be provided.

2.15.4 The stability and settlement of the structure during pile installation are to be considered. Analyses are to be carried out for situations where no piles are installed and for when piling is only partially installed.

2.15.5 Details of the proposed method of installation and its associated monitoring system are to be submitted.

2.15.6 Settlement and tilt of the structure during installation are to be recorded.

2.16 Pile design requirements

2.16.1 Piles are characterised by being relatively long and slender and having a length to diameter ratio or width ratio generally greater than ten.

2.16.2 Pile axial capacity shall meet the requirements of the adopted standard, taking into account the appropriate action and resistance factors, or factor of safety, as required.

2.16.3 The efficiency of the group, that is its capacity compared to the sum of the capacities of individual piles within the group, is to be checked. In addition, for close pile spacings the stiffness of the pile may require modification due to group effects.

2.16.4 Consideration is to be given to the possible formation of a post-hole (i.e. gap between the soil and the pile) at the pile head and its effect on capacity.

2.16.5 The influence of pile shoes, internal stiffeners and any other protrusions should be accounted for within the pile capacity and installation assessments.

2.16.6 For driven piles the effects of driving shall be taken into account in the fatigue damage assessment.

2.16.7 Interaction between lateral loads and axial capacity, or the reverse effect, should be considered where appropriate.

2.17 Axial capacity

2.17.1 This sub-Section applies to piles that are either driven or drilled and grouted into the seabed.

2.17.2 If the pile is to be vibro-driven for any part of the pile penetration, then it should be demonstrated that there is no significant effect of vibro-driving on pile capacity. Generally, if the portion of vibro-driving is limited to the first 20 per cent of pile penetration then it is not expected to have a significant effect.

2.17.3 Driven pile capacity may be adjusted for ageing, cyclic and rate effects as demonstrated to be appropriate for the soil types. Cyclic degradation shall be considered where it may be significant.

2.17.4 Other methods than those contained within ISO 19901-4 and API RP 2GEO of determining axial capacity are acceptable, provided they are supported by sufficient evidence of their validity together with appropriate laboratory testing. This includes the Unified CPT Method in Sands (Lehane et al. 2020) and the Unified CPT Method in Clays (Lehane et al. 2021).

2.17.5 For unconventional soils, such as carbonate or volcanic soils, it shall be ensured that appropriate design methodology is used.

2.17.6 No end bearing should be taken for drilled and grouted piles unless it can be demonstrated that there is no infill at the bottom of the drilled hole, or the calculations account for the compressibility of such infill. If end bearing is used in the calculation of capacity or stiffness, then the possible effects of skin friction degradation shall be considered.

2.17.7 For tension loads, no end bearing (or suction) component at the pile tip is to be considered unless this can be justified based on pile configuration, rate of loading and soil permeability.

2.17.8 Pile capacity in rock is to be specially considered.

2.17.9 Consideration should be given to the effect of close spacing of piles, since the ultimate axial capacity of a group can be less than the sum of the individual capacities. This may be determined by consideration of the group as an 'equivalent pier'.

2.17.10 Drilled and grouted pile design shall be specially considered.

2.18 Lateral capacity

2.18.1 For piles, the lateral capacity and pile response are normally to be determined using a beam-column non-linear soil/structure interaction finite element analysis. The non-linear axial and lateral soil resistance/pile deflection is to be modelled using t-z and p-y curves, respectively.

2.18.2 It should be demonstrated that the selected p-y curve methods are valid for the soil conditions at the site. For unconventional soil conditions, consideration should be given to other p-y curve methods specifically developed for those soil types (see Guidance Notes for Offshore Wind Farm Project Certification).

2.19 Installation – Driven piles

2.19.1 Driving stresses and static stresses due to the weight of the hammer are to be considered in the selection of pile driving hammers and pile wall thickness. Driving stresses are also to be included in the assessment of pile fatigue lives. The stresses induced in the pile during driving can be estimated using a wave equation analysis.

2.19.2 Pile buckling checks during driving shall also be performed.

2.19.3 Any effects resulting from the use of a pile template or guide frame should be considered within the pile design. This may include consideration of disturbance caused during frame installation and removal.

2.19.4 A full record of the pile driving operation is to be kept, and is to be submitted to LR. The records of the pile driving operation should include the following details:

- Timing of the various operations.
- Hammer characteristics (stroke and any measurements of striking energy and energy transmitted to the pile head) and blow count with penetration.
- Configuration of the top of the pile, giving the cushion and anvil materials together with primary dimensions.
- State of cushion (number of blows suffered and physical appearance) at the start of driving and time(s) at which the cushion is changed.
- Soil plug measurement on completion of driving.
- Use of pile template or guide frame and any records of operation including inspection of seabed disturbance after template recovery.

2.20 Installation – Drilled and grouted piles

2.20.1 The methods for drilling and grouting and details of the plant and materials are to be submitted to LR for approval.

2.20.2 The construction sequence is to avoid leaving holes open for long periods in soils or rock that are sensitive to exposure to water or drilling fluids.

2.20.3 A specimen record is to be submitted for approval prior to the installation of the first pile.

2.20.4 A full record of the drilling and grouting operation is to be submitted to LR and should include the following details:

- Timing of the various operations.
- Method of drilling.
- Density, viscosity, flow rate and pressure of drilling fluid during drilling.
- Description of returns, if any, from the borings.
- Bit pressure, torque and speed of drilling tools.
- Details of circulation loss and any remedies adopted.
- Hole survey details (the profile and linearity of all holes are to be surveyed to their full depth).
- Details of checks made to determine the existence of any material which has fallen into the hole prior to grouting.
- Final position of any reinforcement or insert piles placed.
- Fluid pressure maintained during drilling and grouting.
- Details of the density, flow rates, grout level and pressure of grout during pumping and total volume of grout pumped (means of monitoring should be specified).
- Details of grout mix design and its constituent materials.

- Programme of grout sampling and testing, including measurements of density and grout crushing strength at 1, 2, 7 and 28 days.
- Grout return level check on completion and grout slump level check at least 12 hours after completion. These grout level checks should be provided relative to seabed.

2.21 Suction pile design requirements

2.21.1 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of suction piles.

2.21.2 The installation tolerances are to be considered when assessing failure modes for the soil.

2.21.3 Consideration should be given to internal soil plug heave.

2.21.4 Consideration should be given to the effect of layered soils on installation.

2.21.5 The effect of any jetting system or similar installation aids is to be assessed.

2.21.6 The installation and retrieval of suction piles shall be assessed.

2.22 Acceptable basis for suction installed pile design

2.22.1 Suction piles should be designed in accordance with industry recognised practice such as ISO 19901-4. In addition, the guideline published by the Offshore Wind Accelerator provides additional guidelines on the design of suction caissons.

2.22.2 In general, it is expected that initial sizing of a suction caisson foundation is performed by use of simplified closed form solution methods. Subsequent to this the sizing should be demonstrated to be suitable using more advanced methods such as finite element analyses. Suction pile analysis is generally performed using either a continuum finite element model or a limit plasticity model of the pile and soil in order to assess appropriate failure modes. Pile response and the determination of soil reaction stresses for structural analysis of the suction pile are to be analysed using non-linear soil/structure interaction finite element analyses.

2.22.3 Suction piles are characterised by having a large diameter and a length to diameter ratio generally less than eight and are considered to be caisson-type foundations if the length to diameter ratio is less than three.

2.22.4 The resistance factors (or factor of safety) for suction piles should be accounted for in the analyses as described within ISO 19902, taking account of whether axial loading, lateral loading or combined axial-lateral loading controls the foundation design.

2.22.5 The influence of pile shoes, internal stiffeners and any other protrusions should be accounted for within the pile capacity and installation assessments.

2.22.6 For tension loads, no end bearing (or suction) component at the pile tip is to be considered unless this can be justified based on pile configuration, rate of loading and soil permeability.

2.22.7 Consideration is to be given to the possible formation of a post-hole at the pile head and its effect on capacity.

2.23 Installation of suction piles

2.23.1 Soil resistance to suction piles is to be determined. The potential for internal soil heave and soil plug failure during installation is to be considered.

2.23.2 The record of installation of piles installed by suction is to be submitted to LR and should include:

- Pile penetration;
- Pressure differential;
- Orientation;
- Verticality.

2.24 General gravity base requirements

2.24.1 Gravity bases should be designed in accordance with industry recognised practice such as ISO 19903 and ISO 19901-4.

2.24.2 A material factor for soil of 1,25 is to be applied to the design undrained shear strength, tangent of the angle of internal friction of the soil and tangent of the angle of interface friction between the soil and the gravity base.

2.24.3 If the gravity base is to be placed on top of rock, then special consideration will be given. Project-specific testing may be required to demonstrate the interface friction between the rock and the underside of the gravity base.

2.24.4 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of gravity base foundations. The installation tolerances are to be taken into account when assessing failure modes for the soil.

2.24.5 The stability and characteristics of any ballast will require special consideration. Any ballast should be capable of withstanding cyclic loading.

2.24.6 The gravity base is to have sufficient strength to account for the stresses due to the applied loading conditions.

2.24.7 Wave loads on the seabed are to be considered when such loads are unfavourable to stability.

2.25 Foundation movements

2.25.1 Calculations of foundation movements are to include the effects of short-term and long-term loading.

2.25.2 The following possible causes of vertical, horizontal or differential movements are to be investigated:

- Immediate settlement.
- Secondary settlement due to steady, or permanent, loading.
- Long-term consolidation and settlement due to dynamic, static and steady loading.
- Recoverable displacements due to transient loading.
- Differential settlement due to variations in soil conditions over the foundation base area.
- The extent of horizontal movements and tilt are to be assessed. The relative magnitudes of recoverable and nonrecoverable displacement are to be determined.
- Subsidence due to reservoir extraction.

2.26 Foundation contact pressure

2.26.1 Complete contact with the seabed is to be maintained at all times and the stresses imposed by the foundations on the seabed are to be compressive under all loading conditions.

2.26.2 Calculations of the local contact stresses between the foundation and the seabed are to take into account the results of the seabed survey.

2.26.3 Local soil reactions on gravity foundations are to be based on the highest expected values of soil strength in the upper soil layers.

2.26.4 Unless specifically considered in the design, any voids remaining beneath the foundation after installations are to be filled with cementitious grout (for example).

2.27 Seabed penetrating elements

2.27.1 Where foundations have skirts, dowels or other seabed penetrating elements which transfer load to the seabed, the effect of these components is to be taken into account when determining the efficiency of, and loads in, the foundations for bearing capacity and sliding resistance. These items are to be designed as structural members.

2.27.2 The resistance of skirts, dowels and other seabed penetrating elements to penetration of the seabed during installation of the foundation and their effect, if any, on water flow beneath the foundation during installation are to be taken into account in the design calculations.

2.27.3 The penetration resistance of elements such as skirts and dowels is to be based on conservative (upper bound) estimates of soil strength. Also, by considering more typical penetration resistances, account may be taken of the foundation in formulating possible eccentric ballasting requirements.

2.27.4 The gravity base installation should ensure that any skirts or other seabed penetrating elements penetrate as required by the design.

2.27.5 Provision is to be made for the relief of water pressure generated within the skirts during installation of the structure.

2.28 Installation of gravity base foundations

2.28.1 The positioning of the foundation is to be properly related to the location of the site investigation.

2.28.2 Any significant obstructions identified by the seabed survey carried out prior to the installation are to be removed before emplacement.

2.28.3 Differential ballasting may be required to accommodate non-uniform soil properties or a sloping seabed. In general, reduction of pressure beneath the foundation is not to be used to aid installation, unless it can be demonstrated that wash out or flow of soil will not occur.

2.28.4 Records of settlement and tilt of the structure are to be made during installation and properly correlated to those required to be kept while the structure is in service.

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Section 1
General requirements

1.1 Scope

1.1.1 This Chapter outlines the Lloyd's Register (herein after referred to LR) certification structural design requirements for a fixed offshore platform associated with the oil and gas or wind industries.

1.1.2 The design should also meet all local regulations which apply at the platform site, including safety regulations.

1.1.3 The requirement of this Chapter is applicable to the design of new and existing jacket and topsides structures. It is anticipated that bottom fixed offshore structures presently classed based on LR Rules comply with applicable requirements of the present Chapter or are based on other relevant National or International Standards (agreed with LR).

1.2 Recognised codes and standards

1.2.1 This Recommended Practice (RP) provides guidance for certification and hence supplements, rather than replaces, recognised international design codes. The RP is based on the requirement of the ISO 19900 suite of standards for petroleum and natural gas projects.

1.2.2 Other recognised International Standards which give an equivalent level of safety can be considered. The standards chosen should be agreed with the certifier at the earliest practicable stage of the project.

Section 2
Design principles

2.1 Limit state method of design

2.1.1 This RP is based on the requirement that structural design is undertaken following the limit state procedure defined in ISO 19900 and ISO 19902 or other recognised International Standards that give an equivalent level of safety if the use of such standard has been agreed upon with the certifier.

2.1.2 When the limit state method of design is proposed for the structure, the design methods, load combinations and partial factors should be based on ISO 19902. If other codes and standards are used, load combinations and partial factors are to be agreed with LR.

2.1.3 The following four categories of limit states are considered as relevant:

- Ultimate Limit State (ULS);
- Serviceability Limit State (SLS);
- Fatigue Limit State (FLS);

- Accidental Limit State (ALS).

2.1.4 Alternative design approaches, such as probabilistic methods and structural reliability analysis, may be accepted by the certifier if justified and documented to provide reliability consistent with that implicit in the ISO 19902 standard.

2.2 Ultimate Limit State (ULS)

2.2.1 The strength of the structure should be sufficient to ensure that under the worst combination of extreme loads (definition) the structure will not collapse, buckle or implode. Consideration is also to be given to the mode of failure. In general, the initiation of failure of primary members by compression or shear is to be avoided.

2.3 Serviceability Limit State (SLS)

2.3.1 The serviceability limit is selected to ensure that the structure will meet the requirements for deflection under service conditions.

2.3.2 The deflection of the structure or any part of the structure is to be limited, such that it does not adversely affect the efficiency of the structure. Deflections are to be compatible with the degree of movement acceptable for the operation of services, etc. Any particular requirements should be specified by the Owner.

2.4 Fatigue Limit State (FLS)

2.4.1 It should be demonstrated that the structure is not susceptible to fatigue failure. Fatigue analysis of critical areas is to be carried out based on the principle of cumulative damage.

2.5 Accidental Limit State (ALS)

2.5.1 The layout of the structure and the interaction between the structural members are to be such as to ensure a robust and stable design.

2.5.2 Consideration is to be given to redundancy and the possibility of progressive collapse. The designer must ensure that there is sufficient strength or redundancy to prevent progressive collapse. This requirement relates particularly to accidental or exceptional loads. Consideration is to be given to both the intact and post-damaged condition.

2.5.3 Environmental return periods for use in post-damaged conditions should be in accordance with ISO 19902 or as stipulated by the agreed reference standard.

Section 3
Loads and load combinations

3.1 General

3.1.1 The requirements in this Section define the loads and load combinations to be considered in the overall strength analysis of the fixed offshore structure.

3.1.2 The design should take into account realistic loading conditions, including buoyancy, gravity and functional loadings together with relevant environmental loadings. Due account is to be taken of the effects of wind, waves, currents, motions, moorings and ice, and, where necessary, the effects of earthquake, seabed-supporting capabilities, temperature, fouling, etc. Where applicable, the design loadings indicated herein are to be adhered to for all types of offshore units.

3.1.3 The design environmental criteria determining the loads on the unit and its individual elements are to be based upon appropriate site-specific data that should be developed in accordance with ISO standards or equivalent.

3.2 Loads

3.2.1 There are various categories of load conditions that should be considered for the design of the offshore structure. These include the following:

- permanent actions (G);
- variable actions (Q);
- environmental actions (E);
- accidental actions (A);
- actions resulting from imposed deformations (D).

3.3 Permanent loads

3.3.1 Dead loads include any permanent loads that do not change during the design life of the structure. They mainly consist of the weight of platform in the air including the buoyancy loads, permanent equipment loads, external hydrostatic pressure up to the mean water level etc. Wherever the dead loads are calculated based on the software these should be further calibrated using the weight control report.

3.4 Live loads

3.4.1 Live loads are loads associated with operations of the platform. Live loads can be classified as variable and dynamic loads. Variable loads change in magnitude and position very slowly, whereas dynamic loads can induce significant dynamic effect on the structure.

3.4.2 Live loads are related to the operation of the unit and can vary in magnitude. The following can be considered as examples:

- weight of stored materials and equipment;
- loads associated with process operation;
- crane and helicopter operations;
- Marine growth
- Snow and ice loading where appropriate

3.5 Environmental loads

3.5.1 Environmental loads are loads that are directly or indirectly associated with environmental actions (wind, wave and current).

3.6 Deformation loads

3.6.1 Deformation loads on the structure should be considered. These can result from changes in temperature.

3.7 Accidental loads

3.7.1 Accidental loads are loads that occur as a direct result of events arising from two different types of hazards: identified accidental events and abnormal environmental actions.

3.7.2 Identified accidental events can include collision with vessels, the impact from dropped objects, fire or explosion. With this type of hazard designers can choose between avoiding a hazard (e.g. by taking special preventive measures such as operational restrictions), minimising the structural consequences of the considered hazard (e.g. by implementing protective measures) or designing for the hazard.

3.7.3 Abnormal environmental actions can occur as a result of very rare and abnormally severe environmental conditions. The appropriate return period for the abnormal design situation for abnormal actions due to the environment should be determined based on the requirements of ISO 19902 or the alternative agreed standard. Typically, the abnormal design situation is based on a return period of 10000. This return period is an indication of the order of magnitude rather than a precise number, since accurate databases for such small probabilities of exceedance rarely exist.

3.7.4 The abnormal design situation for abnormal earthquake actions may be based on the Abnormal Level Earthquake, according to ISO 19901-2.

3.8 Load combinations

3.8.1 Load combinations and load factors for use in the design of steel structure units should be adopted in accordance with ISO 19902, or alternative agreed reference standards, for all the relevant design conditions and limit states.

■ *Section 4*
Structural assessment methods

4.1 General

4.1.1 There are three different types of assessment method that can be used in the assessment of the platform. These are described in detail in ISO 19902. A brief outline is given below.

4.2 Design level analysis

4.2.1 This is a linear analysis, with the exception of the pile-soil interaction, based on recommended codes of practice for in-place strength and fatigue life assessment. It is intended that all new-built structures should meet the requirements of design level analysis.

4.2.2 When an in-place strength check fails the acceptance criteria, mitigation methods should be considered. In case of reassessment of existing structures, where design changes are not possible and mitigation measures are impractical, Ultimate Strength Analysis may be carried out.

4.3 Ultimate Strength Analysis

4.3.1 This is a non-linear pushover type of analysis, which can evaluate the redundancy of the platform and calculate the Reserve Strength Ratio (RSR).

4.3.2 This type of analysis provides an alternative approach based on the Global System Failure, instead of on the Conventional Component Failure.

4.3.3 Accurate computer models and sufficient modelling details to simulate the failure modes, along with suitable software, are a few of the important aspects required to perform an Ultimate Strength Analysis.

4.3.4 For results that are non-compliant with the acceptance criteria, Reliability-Based Assessment can be considered. Different mitigation procedures can also be considered.

4.4 Reliability-Based Assessment

4.4.1 This type of assessment is based on the probabilistic modelling of load and resistance, and evaluates probability of failure of the system.

4.4.2 Alternative mitigation procedures should be considered if the targeted probability of failure could not be achieved.

■ *Section 5*
Structural design for in-service condition

5.1 General

5.1.1 The requirements in this Section define the different types of analysis to be performed for the design of jackets in the in-service condition.

5.1.2 The design of jackets should include the following conditions:

- In-place conditions, including coupled non-linear interaction of the soil-pile system with the jacket;
- Fatigue analysis for in-place conditions; including damages during installation e.g pile driving or transportation fatigue
- Dynamic analysis;
- Seismic analysis.

5.2 In-place condition

5.2.1 A three-dimensional finite element model should be developed for carrying out in-place analysis. The computer model generally includes jackets, piles and an appropriate simulation of the deck. The modelling should also include soil springs to account for non-linear pile/soil interaction.

5.2.2 The design should take into account realistic loading conditions, including buoyancy, gravity, and functional loadings together with relevant environmental loadings. Due account is to be taken of the effects of wind, waves, currents, motions, moorings and ice, and, where necessary, the effects of earthquake, seabed-supporting capabilities, temperature, fouling, etc. Where applicable, the design loadings indicated herein are to be adhered to for all types of offshore units.

5.2.3 The in-place strength assessment, carried out to appraise the compliance of the structure with the agreed codes and standards, should include the following, as a minimum:

- Member strength checks;
- Joint strength checks;
- Pile (below mudline) strength checks;
- Pile factors of safety;

- Hydrostatic collapse checks for bouyant members;
- Grouted connection strength checks (if applicable).

5.3 Dynamic analysis

5.3.1 In-place strength assessment can be carried out as a static analysis if it is demonstrated that the fundamental natural period of the structure does not exceed three seconds. If the natural period exceeds three seconds, the structure is deemed dynamically sensitive and dynamic response effects should be included.

5.3.2 The computer model used for dynamic response analysis should take due consideration of the global mass modelling of the platform, and in particular of the hydrodynamic masses (entrapped water and water added masses) of the jacket and appurtenances. Also, the correct mass location and direction shall be modelled.

5.3.3 There are various methods available for dynamic analysis of offshore steel platforms subject to wave loading. ISO 19902 describes methods with increasing degrees of complexity, from quasi-static linear analysis, which is appropriate when dynamic effects can be represented by the dynamic amplification factor (DAF), to full transient dynamic non-linear analysis, in which the environmental action is simulated in time, which is appropriate for dynamically complex design situations.

5.4 Fatigue condition

5.4.1 Fatigue analyses of jacket and topsides structures are carried out to establish the accumulated damage at welded joints and other fatigue-susceptible structural details, when subject to cyclic loading.

5.4.2 In addition to damage incurred during operation, fatigue analysis should account for damage induced under temporary conditions – fabrication, transport, installation, pile driving, etc.

5.4.3 While fatigue damage of the platform substructure is primarily driven by waves, wind fatigue is of major importance for dynamically sensitive topsides structures such as flares and vents.

5.4.4 When modelling substructures, it should be ensured that all appurtenances and appurtenance to structure connections are accurately represented to capture the wave loads and local cyclic stresses. These include, for example, boat landings, conductor guide frames, caisson supports, caissons, etc.

5.4.5 The fatigue analysis can be carried out using the deterministic or spectral method, depending on the dynamic properties of the structure. Dynamically sensitive structures should be assessed using the spectral analysis method. Both methods involve stepping selected wave heights and frequency through the structure based on the wave scatter diagram presented in the metocean report. The local joint stress ranges along with the stress concentration factors are used to determine the fatigue damage.

5.4.6 Appropriate S-N curves should be selected based on the location of the joint and type of details.

5.4.7 The minimum fatigue life of all platforms shall be twice the design life of the platform. The required fatigue life for a particular joint or detail will depend on its criticality and accessibility for inspection and repair. The appropriate design fatigue life is determined by specifying the fatigue design factor.

5.4.8 The S-N curves, joint classification, and fatigue design factors should be based either on ISO 19902 or, if agreed with the certifier, on other recognised industry standards.

5.4.9 The fatigue damage should be calculated for primary tubular joints, nodal joint welds, circumferential welds with thickness transitions, closure welds, penetrations, piles, conical transitions, support stubs, ring stiffeners, diaphragms and attachment welds within a jacket structure.

5.4.10 Weld toe grinding may be used during fabrication as a fatigue improvement requirement.

5.5 Seismic analysis

5.5.1 Structures located in seismically active areas should meet the strength requirements and ductility requirements.

5.5.2 Structures should be checked for the following two levels of seismic excitations:

- Strength Level Earthquake (SLE);
- Abnormal Level Earthquake (ALE).

5.5.3 Strength Level Earthquake checks are intended to ensure that the platform has sufficient strength and stiffness such that the platform should not have structural damages in the event of an earthquake which has a reasonable likelihood of not being exceeded at the site during the life of the structure.

5.5.4 Abnormal Level Earthquake checks are intended to ensure that the structure and foundation have sufficient reserve strength, displacement and/or energy dissipation capacity to sustain large inelastic displacement reversals without collapse during rare, intense Ductility Level Earthquake (DLE) motions, although structural damage may occur.

5.5.5 Strength Level Earthquake analysis is usually done based on the response spectrum method. The non-linear static pushover analysis method is usually used to determine the global failure mechanism for Abnormal Level Earthquake. The non-linear time history analysis method is performed for further refinements.

5.5.6 It should be ensured that accelerations for SLE and ALE do not affect performance of different equipment located on the structure.

5.6 Preservice condition

5.6.1 Although transportation and installation are outside the scope of the RP, LR requires to be satisfied that the structure is adequate for the loadings resulting from the following conditions:

- Load-out;
- Sea transportation;
- Lift;
- On-bottom stability;
- Stabbing of piles;
- Pile driving;
- Pile driving fatigue;
- Pile sway;
- Pile upending;
- Stabbing of topsides.

Section 6
Structural design for accidental condition

6.1 General

6.1.1 The requirements in this Section define the different types of accidental analysis to be performed for the design of installations

6.1.2 The design of installations should include the following conditions:

- Abnormal weather loading;
- Vessel collision analysis;
- Fire and blast scenarios;
- Dropped objects;
- Seismic events.

6.2 Abnormal wave events

6.2.1 Most of the existing jacket structures have been designed based on the requirements of API RP 2A-WSD, in which a minimum air gap of 1,5 metres was required for a design wave of a 100-year return period. However, these requirements were derived based on the Gulf of Mexico region, where extreme events are hurricane dominated. The platforms in these regions are de-manned prior to the occurrence of extreme events as the path of the hurricanes can be accurately predicted well in advance. This criterion is no longer considered valid for regions, such as the North Sea, with higher uncertainty in prediction of rare wave events.

6.2.2 The current codes, including ISO 19902, now require a positive air gap with an annual probability of exceedance of 10-4 as part of the ALS strength requirements.

6.2.3 The wave crest elevation with an annual probability of exceedance of 10-4, or a 10000-year return period, is in many regions, including the North Sea, significantly higher when compared to the criteria of 100-year crest elevation +1,5 m.

6.2.4 For existing offshore fixed platforms, it is commonly found that the air gap does not meet the 10000-year criteria. In these cases, the wave impact on the deck must be assessed. The negative air gap is not permitted for new platforms except locally where special studies are to be performed.

6.2.5 The wave in deck load is complex and influenced by factors including the type of wave, level of inundation, deck configuration, wave phase and deck proportions.

6.2.6 The silhouette wave in deck load procedure given in ISO 19902 was derived based on simple structures in wave tank tests in which tropical cyclone and winter storm waves were modelled. The simplified silhouette method should only be applied when it can be shown to be appropriate.

6.2.7 Analytical methods such as computational fluid dynamics (CFD) or the momentum flux method are suggested as alternatives for calculation of wave in deck forces. It is always recommended that wave forces are calibrated based on wave tank tests. The wave in deck load calculation should also account for the considerable dynamic effects caused by the impulsive nature of the wave in a deck event.

6.2.8 The performance of the structure under the wave-in-deck impact scenario is assessed by carrying out non-linear pushover analyses in accordance with the requirements of ISO 19902 to demonstrate that the substructure has adequate structural integrity to survive this event.

6.2.9 A hazard curve is developed specifically for the jacket by plotting global base shear for the jacket (excluding wave in deck loads) for 100-year and 10000-year return period (unfactored) environmental loads. The wave in deck loads are then superimposed on the hazard curve from the point the wave crest just touches the underside of the deck.

6.2.10 The reduced return period of collapse due to wave in deck is then read off the hazard curve. If the return period does not meet the requirement of the ISO standard, alternative mitigation methods such as de-manning should be considered, such that overall structural risk for the platform meets the as low as reasonably practicable (ALARP) requirements.

6.3 Vessel collisions

6.3.1 The size of the supply vessels that visit offshore installations has increased over the years. The increase in vessel displacement with a greater displaced weight of the support vessel underpredicts ship impact loads associated with the original design and results in a greater risk to the installation and its structural integrity.

6.3.2 ISO 19902 recommends two conditions to be satisfied:

- Low energy level, representing the most frequent condition, based on the type of vessel that would routinely approach alongside the platform (e.g. a supply boat) and that would have a velocity representing normal manoeuvring of the vessel approaching, leaving, or standing alongside the platform. This condition represents a Serviceability Limit State to which the Owner can set their own requirements based on practical and economic considerations.
- High energy level, representing a rare condition, based on the type of vessel that would operate in the platform vicinity, drifting out of control in the worst sea state in which it would be allowed to operate close to the platform. This condition represents an Accidental Limit State in which the structure may be damaged as long as global integrity is not compromised, and progressive collapse does not occur.

6.3.3 The intent of the high energy level impact study is to demonstrate that the jacket and foundation have sufficient ductility and can absorb the energy associated with an impact without causing the progressive collapse of the structure. It should also be ensured that the risers/conductors remain within code design limits if affected by impact and at risk of causing incident escalation.

6.3.4 The primary mechanisms for absorbing the impact energy can be associated with the response of the global structure and foundation, including the impacted member, local denting at the point of impact, and the damage to the colliding vessel. The maximum potential energy absorption capacity of the installation is derived by analysing each of these energy absorbing mechanisms.

6.3.5 The vessel orientation (broadside, stern or bow) during impacts varies the structural damage and the amount of energy absorbed. The vessel's centroid is aligned with the line of impact and, therefore, energy dissipation owing to vessel rotation is ignored.

6.3.6 It should also be ensured that the platform retains sufficient residual strength after the impact to demonstrate that all primary structural components conform to the requirements in accordance with ISO 19902 or as stipulated by the agreed reference standard.

6.4 Fire and blast

6.4.1 A fire and explosion study should be performed to identify the possible hazards associated with the accidental release of hydrocarbon inventory within the platform. For further discussion regarding fire and explosion study requirements, please refer to *Ch 8, 3 Fire safety*.

6.4.2 The objective of the blast design is to provide the best protection to personnel in a blast or fire event and to contain and prevent escalation. It should also be ensured that in the event of a major incident, the structural integrity would be maintained to allow for safe evacuation of the platform. The platform structure, when subjected to blast and/or fire loads, is designed in a practical and economical manner with due consideration of material properties, cost, fabrication, space, maintenance, and operational flexibility.

6.4.3 The safety of personnel, protection of major equipment and isolation of hazardous components should all form part of the design philosophy for blast load cases. In the event of a fire or explosion, it should be ensured that at least one escape route should remain available after the event.

6.4.4 The project's structural design specifications should provide the basis for design for accidental loads, which will determine the analysis method and limitations for the structural behaviour.

6.4.5 Blast requirements should be addressed concurrently with fire resistance requirements. Appropriate fire followed by blast and blast followed by fire events should be considered.

6.4.6 The resistance of the structure should be based upon the ultimate strength, determined from the most critical of collapse pressure (plastic limit of the material or buckling capacity of the panel or member), maximum deformation/ductility ratio, energy absorption or brittle fracture.

6.4.7 The following two levels of blast loading are normally considered for the structural design:

- The strength level blast (SLB), which is defined as a high probability, low consequence event.
- The ductility level blast (DLB), which is defined as a low probability, high consequence event.

6.4.8 The strength level explosion should be designed as a low consequence case resulting in elastic response of the primary structure and essential safety systems remaining operational, with an expected platform re-start after a few days. Primary and secondary steelwork should remain within elastic limits. Local damage to tertiary steelwork is acceptable.

6.4.9 A dynamic amplification factor shall be applied to the SLB explosion loads to translate the blast and structural response to an equivalent static force. Enhanced yield stress may be used for an explosion analysis to account for strain rates and strain hardening on members.

6.4.10 The ductility level explosion could be designed as a high consequence case permitting significant structural damage and plastic deformation of the secondary structure, yet maintaining the integrity of the temporary refuge and the escape route.

6.4.11 A non-linear structural analysis shall be performed to ensure the integrity of structural steel designated as or supporting safety-critical equipment subjected to a DLB explosion load.

6.4.12 The structure is usually subjected to two types of fire scenario:

- Jet fires produced by the release of gaseous inventory;
- Pool fires produced as a result of leakage of low-pressure flammable inventory.

6.4.13 Hydrocarbon fires generate temperatures which can exceed 1500°Cover a large area. At these temperatures, unprotected steelwork would collapse in a short time.

6.4.14 The principal objective of the fire-related design is to ensure that escape routes, temporary refuges, and evacuation routes remain intact and usable for the determined period to allow the safe escape of personnel through the provision of passive fire protection.

6.4.15 Fire and blast are often interlinked extreme events. The occurrence of either after the initiation of the other is a further extreme event which can significantly affect the stability of an already weakened structure.

6.5 Dropped objects

6.5.1 The fundamental requirement is that the structural element should have adequate strength and ductility to maintain its structural integrity under dropped or swinging object loading.

6.5.2 The aim of the dropped or swinging object calculations is to ensure the structure is capable of surviving the design impact, and no collapse mechanism is mobilised. It should also be ensured that the deformation suffered by the structural element should not impair the platform's essential operations.

6.5.3 The amount of damage produced by an object falling onto a structure may vary drastically as a function of various parameters including impact energy and mass, contact surface during impact, location of impact, boundary conditions, object stiffness relative to the structure, and material properties.

6.5.4 The mode of energy absorption and dissipation is very much dependent on the impact area. Small contact areas such as in the case of a drill collar will obviously develop much higher punching shears than those generated by a large container or pallet of similar impact energy.

6.5.5 Current design methods are generally limited to consideration of impacts at the mid-span of panels and beams. However, a simplified shear check should be incorporated to check impacts at the beam ends, assuming a single shear plane as this may govern the beam depth/connection weld size.

6.5.6 It should be ensured that supports to the impacted structure must be capable of sustaining the reaction loads caused by dropped objects.

6.5.7 The accidental impact loads caused by dropped objects from cranes are to be considered in the design of the unit when the arrangements of the unit are such that the failure of a vital structure member could result in the collapse of the structure. Critical areas for dropped objects are to be determined on the basis of the actual movement of crane loads over the unit.

■ *Section 7*
Assessment of existing structures

7.1 Phases of life extension

7.1.1 The four typical phases of life extension studies are presented below:

(a) Phase 1 – This phase includes the review of the original documentation and inspection records and the precise identification of the gaps.
(b) Phase 2 – This phase involves carrying out the required inspection and surveys identified in the gap analysis above.
(c) Phase 3 – This phase includes a desk study describing the analytical assessment of the structure based on the latest loading and conditions.
(d) Phase 4 – This final stage comprises the implementation of mitigation and repair options involving the dynamic input of the client.

7.2 Reassessment requirements of life extension

7.2.1 In-place strength and fatigue reanalyses including foundations should be based on the latest applicable codes and standards.

7.2.2 The reassessment of the structure should be based on the latest metocean report, which would reflect any changes in the environmental data (waves/wind/current). The latest metocean report methodology should comply with the ISO 19901-1 requirements.

7.2.3 Air gap calculation should be based on the minimum deck elevation as presented in ISO 19902, which is based on the assumption that the 10000-year abnormal wave crest should not impinge the lowest deck of the platform.

7.2.4 Reassessment should consider a review of the original pile capacities, driving records and pile fatigue results, as well as a review of any revised soil data applicable to the platform, e.g. using a new methodology like ICP method.

7.2.5 The reassessment should be based on the as-in condition of the platform. The inspection reports should cover scour depths, member damage, fatigue cracks, marine growth, CP measurements and corrosion, including wall thickness measurement of critical members (e.g. members in splash zone).

7.2.6 The up-to-date weight control report, including an up-to-date COG location and loading, should be submitted. The report summary should also highlight all changes tracked back to the original weight report.

7.2.7 A redundancy analysis should be carried out for the up-to-date model (incorporated inspection findings, metocean data, etc.) depending on the fatigue analysis results to establish member criticality.

7.2.8 A ship impact analysis should be carried out if the DWT of the supply vessel has changed or if it was never considered in the original design.

7.2.9 Any changes in the seismic risk category, as per ISO 19901-2, should be considered in the reassessment.

7.2.10 Any proposed future modification should be included in the model.

7.2.11 The inspection strategy and plan is to be updated based on the reassessment results.

7.3 Common issues and challenges related to life extension

7.3.1 The life extension certification involves a review of the exhaustive set of data, including old design information, historical inspection reports, anomaly registers and reassessment reports. It is recommended that the Operators should start to plan the recertification process well in advance, at least a year. This should provide sufficient time for review/analysis, discussions and issues communication between the different parties.

7.3.2 It is very likely that the Owner of the platform has changed over time. As such some of the critical documentation from the original design may not be traceable. This includes:

- The pile driving records from the installation phase of the platform are not always available for some of the ageing platforms;
- Insufficient fabrication inspection records;
- Missing information from drawings related to yield strength and grade of steel.

7.3.3 It is important that the platform should have a good weight database, clearly indicating changes to equipment weights and support location points and deck load. If the information is missing, then an additional survey should be initiated to estimate the current loading on the platform.

7.3.4 The acquisition of relevant site-specific metocean data is always a challenging process. Additional studies should be initiated if there is no up-to-date metocean information available for the reassessment of the platform.

7.3.5 The hydrodynamic loading on the platform could significantly increase if the marine growth exceeds the original design limits.

7.3.6 In some of the operational areas, e.g. gas platforms, there is an increased risk of subsidence. Subsidence or foundation problems can reduce the air gap and can also have serious consequences leading to platform tilt or even collapse. In operational areas of known or suspected subsidence, it should be ensured that above water inspections should include a survey of the gap between the cellar deck bottom of steel and the water level.

7.3.7 Platform subsidence or revised metocean conditions could result in a reduced air gap. This could have potential consequences of local and global damage to the platform.

7.3.8 The current codes and standards have a higher safety factor for fatigue life. This would imply that the structure no longer satisfies the relevant design criteria. Such a risk could be mitigated for example, through additional redundancy checks to assess the criticality of the members or through a frequent inspection interval for critical components of the platform.

7.3.9 Scouring around the platform legs can lead to exposed pile sections. These could result in reduced foundation stiffness for the platform.

7.3.10 The history of inspection and repair (including accidental damage) helps in the understanding of the current condition of the structure. It is important, therefore, that Operators ensure that continuity of knowledge and experience is maintained; for example, history of anode retrofitting records related to dropped object incidents in the platform, additional appurtenances to the platform, etc.

7.3.11 Departures from the original basis of design are often challenging, especially when the new codes and standards have stringent requirements. Some of these challenges include changes to material test temperature requirements, vessel impact requirements, additional air gap requirements, etc.

7.4 Strengthening and repairs

7.4.1 To conclude with, this Section outlines the strengthening and repair indicative techniques that can be considered for an offshore structure:

- Weld grinding;
- Member replacing;
- Underwater welding;
- Member grouting;
- Member or joint clamping;
- Marine growth removal;
- Anode replacement.

Section 8
Assessment of topsides structures

8.1 General

8.1.1 The structural design of main topsides structure can be performed in accordance with industry recognised methods such as those contained within the latest revision of ISO 19902 or API RP2A WSD with respective topside design codes including ISO 19901-3 and API RP 2TOP or similar iinternationally recognised standards.

8.1.2 The non-tubular elements (e.g. open beams and plates) should be designed based AISC/ANSI 360 or Eurocodes EN 1993-1-1.

8.1.3 The topside structure should be designed for ultimate limit state (ULS), serviceability limit state (SLS) and accidental limit state (ALS). The topside structure will also be investigated for fatigue limit state (FLS) due to fatigue loading from main crane and due to sea transportation from construction site.

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Section 1
General requirements

1.1 Types of structures

1.1.1 This Recommended Practice (RP) is intended for fixed offshore platforms associated with petroleum, natural gas or wind energy industries. The Sections in this Chapter provide guidance for certification of fixed offshore units built in reinforced and/or pre-stressed concrete.

1.1.2 This Chapter only considers the design of structural concrete elements of the unit. The guidance on structural design of topsides and steel structures associated with concrete substructure is provided in *Ch 4 Steel Structures*.

1.2 Recognised codes and standards

1.2.1 This RP provides guidance for certification and hence supplements, rather than replaces, recognised international design codes. This Chapter is based on the requirement that the following International Standards are adopted for the design, *see Ch 1, 2.4 Reference papers*.

1.2.2 Other recognised International Standards which give an equivalent level of safety can be considered. The standards chosen should be agreed with the certifier at the earliest practicable stage of the project.

1.3 Submission of calculations and drawings for certification

1.3.1 Drawings, calculations, data and specifications are to be as applicable, including as a minimum:

(a) Concrete, reinforcement and post-tensioning (if applicable) specifications.
(b) Reports and calculations demonstrating compliance of the primary and secondary concrete structure with applicable design codes.
(c) Reports and calculations demonstrating adequacy of the tertiary concrete structures, if identified as critical with respect to safety and environment, against applicable codes.
(d) Reports and calculations demonstrating adequacy of the integration of the steel structures connecting to concrete substructure – topsides connection, embedment plates, major riser/j-tube/caisson/access openings, etc.
(e) Detailed drawings showing overall concrete dimensions, reinforcement and post-tensioning (if applicable) sizes and positions.
(f) Bar bending schedules for supporting information.

Section 2
Design principles

2.1 Limit state design

2.1.1 This RP is based on the requirement that structural design is undertaken following the limit state procedure defined in ISO 19900 and ISO 19903 or other recognised International Standards which give an equivalent level of safety, if use of such standard has been agreed with the certifier.

2.1.2 Alternative design approaches, such as probabilistic methods and structural reliability analysis, may be accepted by the certifier if justified and documented to provide reliability consistent with that implicit in the ISO 19903 standard.

2.1.3 Return periods to be considered for environmental loads under different limit states should be in accordance with ISO 19900 standards.

2.2 Ultimate Limit State (ULS)

2.2.1 The strength of the structure should be sufficient to ensure that under the worst combination of extreme loads the structure will not collapse, buckle or implode. Consideration is also to be given to the mode of failure. In general, the initiation of failure of primary members by compression or shear is to be avoided.

2.3 Serviceability Limit State (SLS)

2.3.1 The serviceability limit is selected to ensure that the structure will meet the requirements for deflection, durability, liquid tightness and cracking under service conditions.

2.3.2 The deflection of the structure or any part of the structure is to be limited such that it does not adversely affect the efficiency of the structure. Deflections are to be compatible with the degree of movement acceptable for the operation of services, etc. Any particular requirements should be specified by the Owner.

2.3.3 The durability of the structure is dependent upon the mix design, the concrete cover, control of cracking by the reinforcement, and exposure conditions. Requirements for the concrete mix and cover are given in *Ch 5, 5 Materials and durability*.

2.4 Fatigue Limit State (FLS)

2.4.1 It should be demonstrated that the structure is not susceptible to fatigue failure. Agreement is to be reached with the certifier on the areas of the structure which are potentially vulnerable to fatigue.

2.4.2 Fatigue analysis of critical areas is to be carried out based on the principle of cumulative damage, *see also Ch 5, 4.6 Material properties 4.6.3* and *Ch 5, 4.6 Material properties 4.6.5* for further recommendations relating to fatigue analysis and performance criteria.

2.5 Accidental Limit State (ALS)

2.5.1 The layout of the structure and the interaction between the structural members are to be such as to ensure a robust and stable design.

2.5.2 Consideration is to be given to redundancy and the possibility of progressive collapse. The designer must ensure that there is sufficient strength or redundancy to prevent progressive collapse. This requirement relates particularly to accidental or exceptional loads. Consideration is to be given to both the intact and the post-damaged condition.

■ *Section 3*
General loads and load combinations

3.1 General

3.1.1 The following loads should be defined in accordance with ISO 19903, the agreed reference standard and *Ch 4 Steel Structures* of this RP.

3.2 Permanent loads

3.2.1 Permanent loads include any loads that are not expected to change during the design life of the structure. The following can be considered permanent loads:

(a) Weight of structure;
(b) Weight of permanent ballast and equipment;
(c) Buoyancy loads;
(d) External hydrostatic pressure up to the mean water level.

3.3 Live loads

3.3.1 Live loads are related to the operation of the unit and can vary in magnitude. The following can be considered as examples:

(a) Weight of stored materials and equipment;
(b) Loads associated with process operation;

(c) Crane and helicopter operations;
(d) Marine fouling
(e) Snow and ice loading where appropriate.

3.4 Environmental loads

3.4.1 Environmental loads are loads that are directly or indirectly associated with environmental actions – wind, wave and current.

3.4.2 The assessment of environmental loads should take into account the following service-related factors:

(a) Site-specific environmental conditions;
(b) Long-term service effects at a fixed location;
(c) Range of storage loading conditions.

3.4.3 Where model tests are carried out, actions determined by model test should be validated by comparison with analytical solutions or with the results of prior appropriate test programmes.

3.4.4 New built structures are expected to meet the ISO 19903 criteria with respect to deck elevation, hence the wave loading on the topsides deck is not expected to be a relevant load case. In instances of insufficient air gap where it needs to be demonstrated that the unit can withstand wave in deck scenario it is expected that model testing will be undertaken to validate analytical results in terms of applied loads and structural response.

3.5 Deformation loads

3.5.1 Deformation loads on the structure should be considered. These can result from the following sources, amongst others:

(a) Temperature;
(b) Creep;
(c) Shrinkage;
(d) Pre-stressing.

3.5.2 For concrete structures the effects of cargo temperatures relative to seasonal ambient temperatures are to be considered for both sea and air temperatures, as appropriate for the section being assessed.

3.6 Accidental and abnormal loads

3.6.1 Accidental loads are defined in *Ch 4, 3.7 Accidental loads*. In addition, the failure of an oil cooling system, if fitted, is to be considered.

3.7 Load combinations

3.7.1 Load combinations and load factors for use in design of concrete units should be adopted in accordance with ISO 19903, or alternative agreed reference standards, for all the relevant design conditions and limit states.

■ *Section 4* Analysis and design

4.1 General

4.1.1 The platform structure is to be capable throughout its design life, including during construction and transit conditions, of withstanding all anticipated loads and deformations, both static and dynamic, with a level of safety which complies with the minimum requirements set out in the ISO 19900 suite of standards.

4.2 Codes and standards

4.2.1 Compliance of the structural design against relevant limit states should be demonstrated based on ISO 19903 or an alternative agreed reference standard. The following design aspects should be adequately covered by the referenced standard:

- design principles for durability;
- design principles for watertightness;
- design principles for pre-stressed concrete;
- shell and panel members typical of offshore structures;

- panels subjected to both in-plane and out-of-plane shear;
- multi-axial stress in concrete;
- fatigue of concrete, reinforcement and shear steel;
- second order effects including panel buckling;
- principles for handling water pressure in pores and cracks;
- design principles for discontinuity regions;
- principles for design against imposed deformations;
- increase in strength of concrete with time;
- design for fire resistance;
- design for earthquakes;
- design for embedments;
- partial factors for material.

4.2.2 Where the selected Code or standard does not adequately address all the above areas of design, it should be supplemented by suitable alternatives as agreed by the certification body.

4.3 Design loads and strength of materials

4.3.1 The characteristic strength of materials should be determined according to the relevant design standards and recognised standards for material testing. The partial factors for the material should be such that a safety level consistent with that inherent in ISO 19900 standards is obtained, and is consistent with the partial factors that are used.

4.4 Analysis

4.4.1 The subclauses of this Section supplement, rather than substitute, the specific requirements of the agreed reference standard.

4.4.2 The adequacy of concrete offshore structure analysis will depend on the following:

- accuracy and consistency of structural models;
- modelling of sufficient level of detail;
- suitability of analysis type used;
- consideration of all the relevant design conditions and limit states;
- adequate representation of the foundation of the structure;
- effective management of interdisciplinary interfaces, such as, for example, between concrete design engineers and topsides designers, hydrodynamicists, geotechnical engineers, etc.

4.4.3 The analysis should be verified to provide confidence in the results obtained. Where assumptions are made to simplify the analysis to enable performance of a particular calculation method, these should be clearly recorded in the documentation or calculations. The effects of such assumptions should be quantified and incorporated as necessary.

4.4.4 Each structural analysis should be adequately documented to record its extent, assumptions, applicability, input data, verification and the results obtained.

4.4.5 Computer software used to perform the analysis should comply with a recognised international quality standard or should be validated for its intended use prior to the start of the analysis. Element types, action applications, meshing limits and analysis types to be used in the structural analysis should all be included in the validation.

4.4.6 Where finite element analysis is performed, consideration should be given to the inaccuracy inherent in the element formulation, particularly where lower order elements or coarse element meshes are used. Validation and ‘benchmark’ testing of the software should be used to identify element limitations and the computer modelling should be arranged to provide reliable results.

4.4.7 Special forms of analysis for concrete structures, such as the strut and tie approach, should conform to accepted theories and should adhere to the general principles of civil/structural engineering. Unless the method is well known and understood throughout the industry, references to source material for the method being used should be provided in the documentation or calculations.

4.4.8 Non-linear finite element analysis may be used to demonstrate ultimate strength of the structure or the strength of complicated two-dimensional and three-dimensional regions. Software used for this purpose should be subject to the same validation requirements as above. Validation of non-linear analysis software used in this way should include at least one comparison with experimental results or with a reliable worked example of a similar detail.

4.5 Physical representation

4.5.1 It is acceptable to consider nominal sizes and dimensions of the concrete cross-section in structural analysis, provided that tolerances are within the limits set out for the construction and appropriate partial factors for material are used. Geometrical and material tolerances considered should be consistent with the International Standard adopted for design.

4.5.2 Where as-built dimensions differ from nominal sizes by more than the permissible tolerances, the effect of this dimensional mismatch should be incorporated in the analysis. The effect of tolerances should also be incorporated in the analysis where action effects and hence the structural design are particularly susceptible to their magnitude (imperfection bending in walls, implosion of shafts, etc.).

4.5.3 Concrete cover to nominal reinforcement and positioning of pre-stressing cables may be provided where these are defined explicitly in detailed local analysis. Again, this is subject to construction tolerances being within the specified limits and appropriate partial factors being applied to component material properties.

4.5.4 The effects of wear and corrosion should be accounted for in the analysis where relevant and where adequate measures are not provided to limit such effects.

4.5.5 It will normally be sufficient to consider centreline distances as the support spacing for beams, panels, etc. In certain circumstances, however, face-to-face distances can be permitted with suitable justification. The effect of eccentricities at connections should be considered when evaluating local bending moments and stability of the supporting structure.

4.6 Material properties

4.6.1 Material properties used in the analyses of a new design should reflect the materials specified for construction. For existing structures, material properties may be based on statistical observations of material strength taken during construction or derived from core samples extracted from the concrete.

4.6.2 For most limit states it is normally acceptable to simulate the concrete by equivalent linear elastic properties. Unless a different value can be justified, the modulus of elasticity of plain concrete may be used as the modulus of reinforced concrete in such an analysis. The value used should be in accordance with the agreed reference standard. For actions that result in very high strain rates, the increase in concrete modulus of elasticity should be considered in the analysis of the corresponding action effects.

4.6.3 Accurate evaluation of concrete stiffness can be particularly important for natural frequencies and for dynamic analysis, and for simulations that incorporate steel components, such as the topsides or conductor framing. Consideration should be given to extreme values of concrete stiffness in such analyses.

4.6.4 Non-linear analysis techniques are often applied to local structural components. It is then typical to discretely model concrete, reinforcement and pre-stressing tendons in such simulations. Where this is the case, each material should be represented by appropriate stress-strain behaviour, using recognised constitutive models.

4.6.5 The density of reinforced concrete should be calculated based on nominal sizes using the specified aggregate density, mix design and level of reinforcement, with due allowance for design growth. For existing structures, such densities should be adjusted on the basis of detailed weight reports, if available. Variation in effective density through the structure should be considered where relevant.

4.6.6 Unless another value is shown to be more appropriate, a Poisson's ratio of $\nu = 0{,}2$ should be assumed for uncracked concrete. For cracked concrete, a value of $\nu = 0$ may be used. A coefficient of thermal expansion of $1{,}0 \times 10^{-5}$ per degree Celsius should be used for concrete and steel in lieu of other information. Where the design of the concrete structure is particularly sensitive to these parameters, they should be specifically determined for the materials in use.

4.7 Soil-structure interaction

4.7.1 The appropriate representation of the foundation of a fixed concrete structure will depend on the type of analysis being undertaken. For static analysis, reactive soil pressures on soil contact surfaces are normally sufficient, but for dynamic analysis or where soil-structure interaction is significant, an elastic or inelastic representation of the foundation will normally be required to provide suitable stiffness. Seismic analysis is typically very dependent on soil properties.

4.7.2 Reactions on the structure from its foundation, or effective foundation stiffness, should be based on general principles of soil mechanics, in accordance with *Ch 3, 2 Geotechnical*. Sufficient reactions should be applied to resist each direction of motion of the structure (settlement, rocking, sliding, etc.). The development of hydraulic pressures in the soil that act in all directions should be considered where appropriate. Consideration should be given to potential variation of foundation pressures across the base of the structure.

4.7.3 The calculations used should reflect the uncertainties inherent in foundation engineering. Upper and lower bounds and varied patterns of foundation reactions should be incorporated and an appropriate range of reactions should be assessed.

4.7.4 Consideration should also be given to the unevenness of the sea floor or soil layers in the seabed, which can potentially cause high local reactions. Foundation unevenness may be considered as actions resulting from imposed deformations in subsequent design checks, in accordance with *Ch 5, 4.3 Design loads and strength of materials*. Other than this, foundation pressures should be considered as reactions, their magnitude being sufficient to counteract all other factored actions.

4.7.5 The analyses should include intermediate conditions during installation, such as initial contact and skirt penetration, as well as the fully grouted permanent condition, where relevant. Disturbance of the seabed due to the installation procedure should be considered in calculating subsequent foundation pressures.

4.7.6 Upper limits of soil resistance should be considered during analysis of the removal of the structure.

4.8 Actions

4.8.1 Actions should be determined by recognised methods, taking into account their variation in time and space. Such actions should be included in the structural analysis in a realistic manner, representing the magnitude, direction and time variance.

4.8.2 Permanent and variable actions should be based on the most likely anticipated values at the time of the analysis. Consideration should be given to minimum anticipated values as well as maximum anticipated values. The former govern some aspects of the design of gravity-based structures.

4.8.3 Hydrostatic pressures should be based on the specified range of fluid surface elevations and densities.

4.8.4 Hydrostatic pressures on structures floating during the transportation, installation and removal stages should include the effects of trim and heel as well as pitch and roll of the structure, owing to influences such as intentional trim, wind heel, wave action or differences in stable attitude of the structure when damaged.

4.8.5 Pre-stressing effects should be applied to the model as external actions at anchorages and bends, or as compatible internal strain effects. In both cases, due allowance should be made for all likely losses in pre-stressing force. Where approximated by external actions, relaxation in tendon forces due to the effect of other actions on the state of strain in the concrete should be considered. Initial pre-stressing forces at lock-off will normally have only local effect but should be considered in analysis if relevant.

4.8.6 Thermal effects are normally simulated by temperatures applied to the surface and through the thickness of the structure. Sufficient temperature conditions should be considered to produce maximum temperature differentials across individual sections and between adjacent structural components. The temperatures should be determined with due regard to thermal boundary conditions and material conductivity. Thermal insulation effects, e.g. due to insulating concrete or drill cuttings, should be considered if present.

4.8.7 Wave, current and wind actions should include the influence of such actions on the motion of the structure while floating. In cases where dynamic response of the structure can be of importance, such response should be considered in determining action effects. Quasi-static or dynamic analyses should be used, in accordance with *Ch 5, 4.5 Physical representation*.

4.8.8 Uncertainties in the centre of gravity of the topsides and in built-in forces and deformations from the transfer of the topsides' weight from barges to the concrete structure should be represented by a range of likely values, the structure being checked for the most critical extreme value.

4.9 Mass simulation

4.9.1 A suitable representation of the mass of the structure is required for the purposes of motion prediction, for actions due to accelerations of masses while floating and for dynamic analyses. The mass simulation should include relevant quantities from at least the following:

- the mass of all structural components, both steel and concrete, primary and secondary;
- the mass of all intended equipment, consistent with the stage being considered;
- the estimated mass of temporary items, such as storage, lay-down, etc.;
- masses of fluids contained within the structure, including equipment and piping contents, oil storage, etc.;
- the mass of solid ballast within the structure;
- the mass of snow and ice accumulation on the structure, where relevant;
- the mass of drill cuttings or other deposits on the structure;
- the mass of marine growth on the structure;
- added water mass;
- added soil mass.

4.9.2 The magnitudes of masses within the structure should be distributed as accurately as necessary to determine all significant modes of vibration (including torsional modes) and all actions due to accelerations of masses for the structural analysis being performed. Particular attention should be paid to the height of topsides equipment or modules above the structural steelwork.

4.9.3 For quasi-static analyses it is normally only necessary to consider the maximum mass associated with a given design situation for the structure. However, for dynamic analyses this does not necessarily produce the worst response, in particular with respect to torsional modes, and a range of values of mass and centre of gravity should be considered. For a fatigue analysis, the variation in the history of actions should be considered. If appropriate, an average value over the life of the structure may be used. In such cases, it is reasonable to consider a practical level of supply to and operation of the platform.

4.9.4 Calculation of the added mass of water and entrained water moving with the structure should be based on best available published information or suitable hydrodynamic analysis. In lieu of such analysis, this mass may be taken as the full mass of displaced water for small submerged members, reducing to 40 per cent of the mass of displaced water for larger structural members. Added mass effects may be ignored along the axial length of prismatic members, such as the shafts.

4.10 Damping

4.10.1 Damping arises from a number of sources including structural damping, material damping, radiation damping, hydrodynamic damping and frictional damping between moving parts. Its magnitude is dependent on the deformation levels of structural members and soil.

4.10.2 Typical values for damping will be in the range from one per cent to three per cent of critical damping; for seismic analysis, *see Ch 5, 4.19 Seismic analysis*.

4.11 Static linear elastic analysis

4.11.1 It is generally acceptable for the behaviour of a structure or structural part to be based on static linear elastic analysis, unless there is a likelihood of significant dynamic or non-linear response to a given type of action. In such cases, dynamic or non-linear analysis approaches should be performed. Static analysis is always permissible if all actions on the component being considered are substantially invariant with time. If actions are periodic, transient or impulsive in nature, the magnitude of dynamic response should be evaluated and static analysis should only be permitted if dynamic effects are small.

4.11.2 Reinforced concrete is typically non-linear in its behaviour, but it is generally acceptable to determine global load paths and section forces for ultimate, serviceability and fatigue limit states based on an appropriate linear elastic analysis, subject to the restrictions presented below. Non-linear analysis can be required for accidental limit states, Abnormal Level Earthquakes and local analysis.

4.11.3 Linear stiffness is acceptable provided that the magnitudes of all actions on the structure are not sufficient to cause significant redistribution of stresses via localised yielding or cracking. In particular, response to actions caused by deformations is very susceptible to the level of non-linearity in the structure and should be carefully assessed for applicability once the level of cracking in the structure is determined.

4.11.4 Reduction of the stiffness of components should be considered if it can be shown that, for example, owing to excessive cracking, more accurate load paths can be determined by such modelling. Such reduced stiffness should be supported by appropriate calculations or by non-linear analysis.

4.12 Dynamic analysis

4.12.1 Fixed structures with global natural periods greater than 2,5 s can be susceptible to dynamic response due to wave action during in-service conditions, at least for fatigue assessment. Structures in shallow water or subject to extreme wave conditions can exhibit significant dynamic response at lower natural periods owing to the higher frequency content in shallow water or unusually steep waves.

4.12.2 Other situations to which the structure can be subjected, such as waves during sea tow, wind turbulence, vibration, impact or explosion, can also impose dynamic actions of significant magnitude close to fundamental natural periods of the structure or its components. Structures that respond to a given set of actions by significant motion or vibration at one or more natural periods should be assessed by dynamic analysis techniques.

4.12.3 Earthquakes are a particularly severe form of oscillatory excitation that should always require detailed dynamic analysis if the zone of seismic activity produces significant ground motions.

4.12.4 Where dynamic effects can be significant, global dynamic response can often be evaluated by using a simplified model representation of the structure; in some cases dynamic effects can be assessed by the calculation of natural periods and the evaluation of dynamic amplification factors. In evaluating dynamic amplification factors for wave action, consideration should be

given to higher frequency components of wave and wind action that occur as a result of drag loading, sharp crested shallow water waves, ringing, etc.

4.12.5 Where substantial dynamic response of the structure is predicted, having magnitudes at critical sections exceeding those predicted by static-only analysis, detailed dynamic analysis should be required. Dynamic analysis should also be required where more than one mode of motion or vibration of the structure is significantly excited by the applied actions, as is the case for seismic response.

4.12.6 Where dynamic effects are relatively insignificant, a quasi-static analysis of the structure or its components may be performed, and dynamic effects may be included in accordance with Ch 5, 4.13 Quasi-static analysis.

4.12.7 Where dynamic response is likely to be relatively important, a full dynamic analysis should be performed to quantify such effects. Appropriate mass and damping simulations should be applied to the structure to enable the natural modes of vibration to be determined with accuracy.

4.12.8 Dynamic analysis will normally require a linearised simulation of the soil stiffness for in-service conditions. This stiffness should be determined with due allowance for the expected level of excitation on the foundation.

4.12.9 Actions applied to the structure or its components should include all frequency content likely to cause dynamic response. The relative phasing between different actions should be rigorously applied.

4.12.10 Harmonic or spectral analysis methods are suitable for most forms of periodic or random cyclic excitation. Where significant dynamic response is associated with non-linear excitation or non-linear behaviour of the structure, of a structural component or of the structure's foundation, then transient dynamic analysis should be required.

4.12.11 Where modal superposition analysis is being performed, sufficient modes to accurately simulate structural response should be included; otherwise a form of static improvement should be applied to ensure that static effects are accurately simulated.

4.12.12 For impulsive actions, such as those due to ship impacts, slamming or explosions, dynamic amplification effects may be quantified by the response of single- or multi-degree of freedom systems representing the stiffness and mass of the structural components being analysed. Transient dynamic analysis will normally be required.

4.13 Quasi-static analysis

4.13.1 Quasi-static analysis refers to any analysis in which the influence of structural accelerations is small enough that dynamic actions can be represented approximately by a factor on static loads or by equivalent quasi-static actions. Both approaches are only appropriate if static and dynamic action effects give an essentially similar response pattern within the structure, but differ in magnitude.

4.13.2 For the former approach, dynamic amplification factors should be used to factor static-only response. Such factors will, in general, vary throughout the structure to reflect the differing magnitudes of static and dynamic response. For columns or shafts of a structure, appropriate local values of bending moment should be used. Base shear, overturning moment and soil pressure are representative responses for the structure's base. For the latter approach, additional actions should be applied to the structure to represent the incremental effects due to acceleration of masses. All actions applied in a quasi-static analysis may be considered constant over time except in the case of non-linear response, where knowledge of the excitation history can be important, and the excitation should be applied to the simulation in appropriate steps.

4.13.3 Factored dynamic results should be combined with factored static effects due to permanent and variable actions, etc. in accordance with the limit states being checked. Partial factors for action for dynamic actions should be consistent with the excitation that causes the dynamic response, normally environmental. The most detrimental magnitude and direction of dynamic excitation should be considered in design combinations.

4.14 Non-linear analysis

4.14.1 Non-linear behaviour should be considered in structural analysis when determining action effects in the following cases:

- where significant regions of cracking occur in a structure such that global load paths are affected;
- where such regions of cracking affect the magnitude of the action effects (imposed deformations, dynamic response, etc.);
- where the structural component depends on significant non-linear material behaviour to resist a given set of actions, such as in response to accidents or abnormal level seismic events;
- where slender members are in compression and deflections can cause significant action effects (imperfection bending or buckling).

4.14.2 A non-linear analysis is able to simulate effects of geometrical and material non-linearities in the structure or in a structural component. These effects increase with an increase in actions and require application of the actions in steps with a solution to the equations at each time step; at each level of actions, iterations to determine equilibrium condition should be carried out.

4.14.3 Non-linear solutions cannot be superimposed. This implies that a non-linear analysis should be carried out for every design situation for which a solution is required.

4.14.4 Non-linear analysis of the global structure or of structural components may be based on a relatively simple structural model. Where linear elastic elements are included in the model, it should be demonstrated that these remain linear throughout the applied actions. Appropriate stress-strain or load-deflection characteristics should be assigned to other parts that behave non-linearly. Deflection effects should be incorporated where relevant.

4.14.5 Non-linear analysis of components to determine their ultimate strength may be performed, provided that the model can appropriately cover all failure modes (e.g. bending, axial force, shear, compression failure affected by reduced effective concrete strength, etc.) and that the concrete tensile stresses are covered by reinforcement. If one analysis is not sufficient to verify all failure mechanisms, separate additional verifications should be carried out.

4.14.6 Complex non-linear analysis of discontinuity regions using finite element methods should not be used without prior calibration of the method against relevant experimental results.

4.15 Probabilistic analysis

4.15.1 It is generally acceptable to base in-service structural analysis of a concrete offshore structure subjected to wave action on the principles of deterministic analysis, predicting responses to specific events. However, where stochastic or probabilistic methods are more appropriate for a particular limit state these should be substituted as needed.

4.15.2 Probabilistic methods typically require linearisation of action effects. This can restrict their use where non-linear response of the structure or structural component is significant. If non-deterministic analysis methods are used, time domain response to transient excitation can be necessary.

4.15.3 Where spectral analysis methods are used for calculating responses to random wave action, a sufficient number of wave conditions should be analysed to ensure that dynamic response close to structural natural periods and close to peak wave energy is accurately assessed.

4.16 Reliability analysis

4.16.1 Reliability assessment of structures is permitted under the provisions of this document to assess the risk of failure of a structure and to ensure that this is within acceptable levels. However, such an analysis is beyond the scope of this International Standard and should be performed in accordance with industry practice according to the state-of-the-art at the time of performing the analysis and by agreement between all parties involved.

4.17 Analyses requirements

4.17.1 The subclauses of this Section supplement, rather than substitute, the specific requirements of the agreed reference standard.

4.17.2 All structural analyses performed should simulate, with sufficient accuracy, the response of the structure or structural parts for the limit state being considered. This can be achieved by appropriate selection of the analysis type with due regard to the nature of applied actions and the expected response of the structure.

4.18 Construction and installation stages

4.18.1 All relevant stages in the life of the structure should be adequately analysed. The agreed reference standard should provide guidance and applicable performance criteria. The following is the list of the temporary design conditions relevant to most offshore fixed concrete structures:

- construction sequence;
- transportation analysis;
- installation;
- deck mating;
- platform removal/reuse;
- fatigue analysis.

4.18.2 Fatigue analysis shall be based on a cumulative damage assessment performed over the design service life of the structure, and shall consider the effects of the range of sea states and directions to which the structure will be subjected. Where relevant, fatigue damage accrued during construction and/or transportation from the construction site to the permanent location shall be included in the accumulation of fatigue damage.

4.18.3 A linear model of the overall structure is generally acceptable for the evaluation of global action effects.

4.18.4 Dynamic effects are likely to be more significant for the relatively short wave periods causing the majority of fatigue damage. Fatigue analysis shall therefore consider the effects of dynamic excitation in appropriate detail, either by quasi-static or by dynamic response analysis. Deterministic or stochastic types of analysis are both permissible, subject to the following requirements.

4.18.5 Where deterministic analyses are deemed adequate, the selected individual waves to which the structure is subjected shall be based on representative spreads of wave heights, periods and directions. For structures that are dynamically sensitive, these shall include several wave periods at or near each natural period of the structure to ensure that dynamic effects are accurately assessed. Consideration shall also be given to the higher frequency content in larger waves that may cause dynamic excitation.

4.18.6 Sufficient wave cases shall be analysed to adequately represent the stress-transfer functions of the structure. Where relevant, non-linear response of the structure shall be incorporated into the analysis using appropriate methods.

4.19 Seismic analysis

4.19.1 Two levels of seismic excitation on a structure should be considered:

- Extreme Level Earthquake (ELE), which should be assessed as a ULS condition.
- Abnormal Level Earthquake (ALE), for which ductile behaviour of the structure assuming extensive plasticity is permissible provided the structure survives.

4.19.2 Where ductile response of specific components of the structure under the ALE event is predicted or considered in the analysis, such components should be designed for ductile behaviour. Expected best estimates of stress/strain parameters associated with ductile behaviour may be adopted in the analyses. Due consideration should be given to the effects of greater than representative strength with respect to the transfer of forces into adjoining members, and for the design of those failure modes that are not ductile, such as shear failure. For those cases where the structure can be designed to the ALE event applying normal elastic analysis and ALS criteria, no special detailing for ductility is required.

4.19.3 Interaction of the structure with its foundation is particularly significant for seismic analysis. The foundation should be modelled with sufficient accuracy for global structural analysis to ensure an accurate assessment of natural periods of vibration and a suitable distribution of soil actions into the structure.

4.19.4 Unless a detailed evaluation is made, internal damping of not more than five per cent should be used to simulate damping from joint structural and hydrodynamic origins for seismic analysis. Any increased value should be subject to justification based on the expected response. Values of soil damping should be determined based on the soil type present.

4.19.5 For the Extreme Level Earthquake (ELE), linear dynamic global structural analysis may be performed using the response spectrum approach. Spectra used should be in accordance with the reference standard. The analysis should incorporate the effect of the structure's response on soil motions, if appropriate.

4.19.6 Where degradation of soil properties and non-linear soil-structural interaction or base sliding are important, a non-linear dynamic time history analysis procedure should be adopted to address these effects; the structure itself may be modelled as linear elastic. Where seismic isolation or passive energy dissipation devices are employed to mitigate the seismic risk, a non-linear time history procedure will be required.

4.19.7 Sufficient modes should be included in the analysis to provide an accurate estimate of total global response. At least two modes should be considered in each of the two principal horizontal directions, as well as a torsional mode about a vertical axis. This requirement may be considered satisfied if it is demonstrated that with the modes considered in the analysis, at least 90 per cent of the participating mass of the structure is included in the calculation of the response for each principal horizontal direction.

4.19.8 One design spectrum may be used in each principal horizontal direction, combined with two-thirds of this spectrum in the vertical direction unless a lesser value can be justified based on site-specific data. These spectra may be combined modally using the complete quadratic combination method and directionally using a square root of the sum of squares approach. Alternative methods are permitted with suitable justification that all seismic action effects are included.

4.19.9 Secondary spectra may be developed for the analysis of structural parts such as the topsides or conductor frames to evaluate the response of parts, appurtenances and equipment not modelled for the global analysis. Alternatively, the design of local components may be based on equivalent quasi-static analysis of such components, based on maximum vertical and horizontal accelerations obtained from the global seismic analysis.

4.19.10 Action effects from seismic analysis should be combined with similar results from permanent and variable actions to produce action effects for structural design. Appropriate directions of seismically induced actions should be considered to maximise these action effects.

4.19.11 For the Abnormal Level Earthquake (ALE), non-linear seismic analysis may be performed using a time history or transient approach. Unless time histories are available by scaling or by other means, they may be developed numerically from the design spectra. Multiple time histories are required to represent the random nature of seismic ground motions.

4.19.12 The computer model for the ALE analysis should include discrete models of all primary components of the structure by using either linear elastic or material non-linear simulations. Deflection effects should be evaluated and permanent and variable actions should be included in the analysis to ensure that second order effects are modelled with sufficient accuracy.

4.19.13 The action effects on structural members that are simulated as linear elastic in either the ELE or the ALE analyses should be evaluated and used to confirm that these components satisfy ULS criteria. Components that demonstrate ductile response should be so designed, and should be assessed against acceptance criteria relevant for the actual limit state with respect to all relevant response parameters.

4.20 Analysis of accidental or abnormal design situations

4.20.1 Accidental loads are to be analysed in accordance with *Ch 4, 6 Structural design for accidental condition*.

4.20.2 Analysis of the structure for accidental events, such as ship or iceberg collision, should consider the following:

- local behaviour of the impacted area;
- global strength of the structure against overall collapse;
- post-damage integrity of the structure.

4.20.3 The resistance of the impact area may be studied using local models. The contact area and perimeter should be evaluated based on predicted non-linear behaviour of the structure and of the impacting object. Non-linear analyses can be required since the structure will generally deform substantially under the accidental actions.

4.20.4 Appropriate boundary conditions should be provided far enough away from the damaged region for inaccuracies to be minimised.

4.20.5 Sufficient deformation of the structure to absorb the impact energy from the collision not absorbed by the impacting object should be documented.

4.20.6 Damaged components of the structure should be removed from this analysis, or appropriately weakened to simulate their reduced strength and stiffness.

4.20.7 Global analysis of the structure under accidental actions can be required to ensure that a progressive collapse is not instigated. The analysis should include the weakening effect of damage to the structure in the impacted area. If ductile response of the structure is likely for the impact actions determined, global non-linear analysis can be required to simulate the redistribution of action effects as section resistances are exceeded. The global analysis may be based on a simple model of the structure sufficient to simulate progressive collapse.

4.20.8 Analysis of the structure in its damaged condition may normally be performed using linear static analysis.

4.21 Design requirements

4.21.1 The platform structure is to be capable throughout its design life, including construction and transit conditions, of withstanding all anticipated loads and deformations, both static and dynamic, with a level of safety which complies with the minimum requirements set out in the ISO 19900 suite of standards.

4.22 Reference standard for design

4.22.1 The design should be performed in accordance with a recognised reference standard, covering all aspects relevant for the structural design of fixed concrete offshore structures. This subclause identifies areas of design that can be relevant, dependent on circumstances. If these areas are applicable they should be appropriately covered by the selected reference standard, supplemented where necessary by additional requirements.

4.22.2 The reference standard to be used should be agreed at an early stage in a project, as the choice of standard can strongly influence the platform geometry and dimensions, while standards not intended for offshore use can be unnecessarily conservative on certain aspects relevant to offshore conditions.

4.22.3 The reference standard to be used should comply with the basic principles of ISO 19900.

4.22.4 However, any standard can be used as a reference standard provided that it is supplemented by additional requirements, where necessary, to ensure that all relevant aspects for the design are properly covered.

4.22.5 The subclauses of this Section supplement, rather than substitute, the specific requirements of the agreed reference standard.

4.23 Design of shell members

4.23.1 Shell types of members are typical in concrete offshore structures; the reference standard should cover design principles applicable to members such as domes and cylinders, where relevant. The design methods should be general in nature, considering equilibrium and compatibility of all six force components giving stresses in the plane of the member (N_x, N_y, N_{xy}, M_x, M_y, M_{xy}) and all limit states.

4.23.2 In assessing shell members for buckling, adequate allowance is to be made for local and global geometric tolerances.

4.23.3 Shell members are to be assessed for a hydrostatic head based on the maximum still water together with the maximum wave pressures.

4.24 Design principles for transverse shear

4.24.1 The reference standard should give the principles required for the design for transverse shear, where the general situation of combinations of simultaneously acting in-plane forces (e.g. tension and compression) and directionality of transverse forces (e.g. principal transverse shear direction) should be covered. The interaction, which is dependent on the directionality of in-plane forces in members like shells, plates and slabs, should be included. Due consideration should be given to the handling of action effects caused by imposed deformations.

4.24.2 Where in-plane deformation forces (excluding pre-stressing) enhance the transverse shear capacity, they should be neglected. This may necessitate performing shear checks both with and without certain deformation loads, e.g. temperature.

4.25 Design for fatigue

4.25.1 The reference standard should give the principles required for the design against fatigue for all possible failure modes. This includes, for example, concrete in compression/compression or compression/tension; transverse shear considering both shear tension and shear compression; reinforcement considering both main bars and stirrups including bond failure; and pre-stressing reinforcement.

4.25.2 Material standards can include certain fatigue-related requirements; these are normally not adequate for offshore applications. The fatigue properties for offshore applications are significantly different, as are those for materials that pass such general material requirements for fatigue. SN-curves representing the five per cent fractile should be prepared for the design of rebars, and in particular for items that have stress concentrations such as couplers, end anchors and T-heads.

4.25.3 The fatigue life factors of safety required are given in *Table 5.5.1 Fatigue life factors of safety for structural components*, *Pt 4, Ch 5, 5.4 Joint classifications, S-N curves and fatigue life improvement methods*, of the *Rules and Regulations for the Classification of Offshore Units, July 2022* and range from one to ten, depending on location in the unit, the ability to inspect or repair and the consequences of failure. The factors chosen are to be agreed for the areas assessed.

4.25.4 All stress variations imposed on the structure during its design life are to be considered in the fatigue evaluation.

4.25.5 The dynamic behaviour of the unit is to be investigated to determine whether the increase in load effects due to dynamic amplification is important. If dynamic effects are considered significant then a response analysis is to be carried out.

4.25.6 Attention should be given to the design and detailing of penetrations, openings and access ways of considering the increased cyclic nature of loading.

4.26 Watertightness

4.26.1 Watertightness control should meet the requirements of the reference standard. Watertightness should be considered under SLS conditions. This should apply to the ingress of water in structures while afloat and during the installed condition in situations where there is internal underpressure. It should also apply to the possibility of leakage, in particular of stored hydrocarbons from structures having internal overpressure. Leakage should also be considered in the design of members for which maintaining a pressure gradient is vital, such as occurs in suction foundations and when using air cushions.

4.26.2 Adequate watertightness or leakage control should be required in ULS and ALS checks for those conditions where leakage can cause collapse or loss of the structure owing to flooding, or where a pressure condition that is required to maintain equilibrium can be lost.

4.27 Design for pre-stressed concrete

4.27.1 The reference standard should give the principles required for the design of pre-stressed concrete, including principles for partial pre-stressing when appropriate.

4.27.2 The effect of the presence of empty ducts during certain phases of the execution period should be considered.

4.27.3 For the final condition the effect of the presence of ducts on the capacity of cross-sections should be considered, in particular if the strength and stiffness of the grout are less than those of the concrete. This also applies if the ducts are not of steel but of flexible materials. Anchorages should be placed in positions and protected in such ways that they are not susceptible for wear or damages.

4.28 Second order effects

4.28.1 The reference standard should give the principles required for the design of all relevant types of members for second order effects, including buckling in the hoop direction of shell types of members.

4.29 Water pressure in pores and cracks

4.29.1 The reference standard should give the principles required to assess the effects of pressure from water or stored fluids penetrating into cracks and pores of the concrete, affecting both the action effects and the resistance. The methods to be used will be dependent on how water pressure is applied in the initial calculation of action effects.

4.29.2 As water pressure will penetrate into shear cracks, shear force capacity enhancement (or shear force reduction) for loads near supports ($x < 2{,}5d$) cannot be applied for shear caused by water pressure.

4.30 Design of discontinuity regions

4.30.1 The reference standard should give the principles for the local design of discontinuity regions where strut and tie models can be used to demonstrate the mechanisms for proper force transfer.

4.31 Design against imposed deformations

4.31.1 The reference standard may additionally give the principles required to permit design against imposed deformations based on strains rather than forces, in all limit states. Where brittle failure modes are involved, such as shear failure in members with no transverse reinforcement, conservative design parameters should be assumed in order not to underestimate the risk of potential brittle failure modes.

4.31.2 Imposed deformations can often be seen as imposed additional strain that affects crack widths in SLS, but with minor effect on section capacity for bending and axial force in ULS. While the effects with respect to transverse shear are more complex, modifications to shear forces due to cracking can be made only where it can be demonstrated that the assumed reduction will take place, using upper values for cracking strength and stiffness, before failing in shear.

4.32 Increase in strength of concrete with time

4.32.1 The reference standard may give guidance for assessing the effect of a gain in strength beyond 28 days and also for assessing the effect of sustained actions, or repeated actions at high stress levels, on the reduction in strength of concrete, where the gain in strength is intended for use in the design.

4.33 Design for fire resistance

4.33.1 The reference standard should give the design principles required for demonstrating adequate fire resistance of members subjected to fire, including relevant material and strength parameters at elevated temperatures.

4.34 Design for earthquakes

4.34.1 Structural design should meet the requirements given in agreed reference standards with respect to seismic analysis and associated performance criteria.

4.34.2 In zones with low to moderate seismic activity, the action effects obtained from an analysis in which the structure is modelled as linear elastic will normally be such that the structural design can be performed based on conventional linear elastic strength analyses, employing normal design and detailing rules for the reinforcement design.

4.34.3 In cases where the seismic action causes large amplitude cyclic deformations, which can only be sustained by employing plasticity considerations, the reference standard should give adequate requirements concerning design and detailing. The regions of the structure that are assumed to undergo plastic straining and to experience excessive deformations should be carefully detailed to ensure appropriate ductility and confinement.

4.35 Design of embedments

4.35.1 The reference standard should give design principles for the anchorage of load-bearing embedment into concrete. Additional reinforcement to transfer all tensile and shear forces into the concrete should be provided if required.

4.36 Partial factors for material

4.36.1 The partial factors for material should be such that a safety level consistent with that inherent in ISO 19900 and this RP is obtained. The material factors to be used will depend on the way the design parameters are defined and specified in the reference standard used, as well as on the corresponding partial factors for action.

4.37 Corrosion protection

4.37.1 The requirements for corrosion protection applicable to steel structures (*see Ch 4 Steel Structures*) are also to apply to the exposed steel components of concrete units.

4.37.2 Either the reinforcement steel and pre-stressing tendons should be actually isolated from the protected external steel or the cathodic protection system should be designed to allow for current drain into the reinforcement as if it were electrically linked. In view of the practical problems of electrically isolating exposed and embedded steel, it is often preferable to consider them linked and make the necessary allowances in the cathodic protection.

■ *Section 5*
Materials and durability

5.1 General

5.1.1 Tests should be made on all proposed materials prior to construction. The tests should be carried out by an independent laboratory accepted by the certifier. Appropriate trials on proposed concrete and grout mixes may also be required. The testing should be carried out in accordance with recognised National Codes or Standards and should be agreed with the certifier.

5.1.2 Certificates for all materials should be submitted to the certifier before work commences on site.

5.1.3 The subclauses of this Section supplement, rather than substitute, the specific requirements of the agreed reference standard.

5.2 Cement

5.2.1 The cement is to comply with the requirements of the agreed appropriate National Codes or Standards.

5.2.2 The following types of cement are, in general, assumed to be suitable for use in structural concrete and/or grout in a marine environment if unmixed with other cements:

5.2.3 Portland composite cements (with silica, fly ash or slag and minimum 80 per cent clinker).

5.2.4 Provided suitability is demonstrated, the following types of cement may also be considered:

(a) Portland composite cements (with other pozzolanas or clinker content below 80 per cent clinker);
(b) Blast-furnace cements (less than 64 per cent clinker);
(c) Pozzolanic cements (less than 64 per cent clinker);
(d) Composite cement (less than 64 per cent clinker).

5.3 Cement replacements

5.3.1 Cement replacements, such as ground granulated blast furnace slag (GGBFS), pulverised fuel ash (PFA) or silica fume, may be combined with Ordinary Portland Cement.

5.3.2 The proportions of the blend and the blended product itself are to comply with recognised National Codes or Standards. In particular circumstances blended proportions outside the range of normal code requirements may be agreed with the certifier.

5.4 Tricalcium aluminate

5.4.1 In order to limit potential sulphate attack, the tricalcium aluminate (C3A) content of the cement, in general, should not exceed ten per cent. It is not advisable to aim for values lower than five per cent.

5.5 Aggregates

5.5.1 Only aggregates with established suitability should be used. Aggregates for structural concrete should have sufficient strength and durability. They should not become soft, be excessively friable, expand or shrink, and should be resistant to decomposition when wet. Aggregates should not react with the products of hydration of the cement to affect the concrete adversely. Marine aggregates should not be used unless they are properly and thoroughly washed to remove chlorides.

5.5.2 Aggregate sources should be investigated and approved for their suitability and for supply dependability.

5.5.3 Aggregate should be delivered with a test report containing, at least, the following:

(a) Description of the source;
(b) Description of the production system;
(c) Particle size distribution (grading), including silt content;
(d) Particle shape, flakiness, etc.;
(e) Porosity and water absorption;
(f) Content of organic matter;
(g) Density and specific gravity;
(h) Potential reactivity with alkalis in cement;
(i) Petrographical composition and properties that can affect the durability of the concrete;
(j) Specified maximum aggregate size based on considerations of concrete properties, spacing of reinforcement and cover to the reinforcement; the maximum aggregate size should not be less than 16 mm.

5.6 Alkali-silica reaction

5.6.1 Some aggregates may be susceptible to deleterious reaction with alkalis normally present in the cement or from other sources including sea water; this produces an expansive reaction which can cause cracking and disruption of the concrete.

5.6.2 It is recommended that, in order to minimise the risk of alkali-silica reaction, an aggregate of good performance record be used. Where this is not possible all aggregates are to be tested for potential reaction.

5.7 Lightweight aggregate

5.7.1 Lightweight aggregate in load-bearing structures should be made from expanded clay, expanded shale, slate or sintered pulverised ash from coal-fired power plants, or from other aggregates with corresponding documented properties. Only aggregates with established suitability should be used.

5.7.2 Lightweight aggregate should have uniform strength properties, stiffness, density, degree of burning, grading, etc. The dry density should not vary by more than ±7,5 per cent.

5.8 Water

5.8.1 Water is to be clean and free from harmful matter, and is also to comply with National Codes or Standards. Sea water is not to be used as mixing or curing water for any concrete containing reinforcement or pre-stressing tendons.

5.9 Admixtures

5.9.1 Air-entraining agents, workability agents and retarding agents may be used. The effects of over and under dosage should be established. Neither calcium chloride nor any admixtures containing more than 0,1 per cent chloride ion are to be used.

5.10 Reinforcing steel

5.10.1 Reinforcement is to comply with an appropriate recognised National Code or Standard. Storage, bending and acceptable welding practices are also to be in accordance with an approved standard agreed with the certifier.

5.11 Pre-stressing tendons

5.11.1 Pre-stressing tendons are to comply with appropriate recognised National Codes or Standards. Handling and tensioning procedures, as well as time periods between installing strands, tensioning and grouting, are to be agreed with the certifier.

5.12 Pre-stressing ducts

5.12.1 Rigid or semi-rigid watertight ducting may be used. Suitable procedures are to be developed for ensuring that the ducts are placed correctly, are watertight and are kept free of debris and concrete during construction.

5.13 Grout (for pre-stressing tendons)

5.13.1 Ordinary Portland Cement is preferred. Sea water is not to be used. Admixtures should be free from products liable to damage the steel or grout itself, such as chlorides, nitrates or sulphides. Expanding agents based on aluminium may be used provided it has been demonstrated that the particular dose rate does not lead to stress corrosion.

5.13.2 The mix is to have appropriate fluidity and bleed properties. These should be verified by trials. For high strength concrete (greater than 65 MPa) consideration should be given to increasing grout strength above the 40 MPa normally achieved.

5.13.3 Grouting procedures are to be developed and approved by the certifier. For long tendons and 'U' tendons, etc. procedures are to be verified with a prototype trial.

5.14 Durability

5.14.1 For durability, three zones of exposure are to be considered for concrete structures:

(a) Submerged zone: that part of the structure below the splash zone defined in *Ch 5, 5.14 Durability 5.14.1.(b)*.

(b) Splash zone: external part of the structure being intermittently wetted by tidal and wave action.

(c) Atmospheric zone: that part of the structure above the splash zone.

5.15 Cement content

5.15.1 In the splash zone, the cement content should not be less than 400 kg/m^3. For reinforced or pre-stressed concrete outside the splash zone, the minimum cement content should be dependent on the maximum size of aggregate, as follows:

(a) Up to 20 mm aggregate requires a minimum cement content of 360 kg/m^3.

(b) From 20 mm to 40 mm aggregate requires a minimum cement content of 320 kg/m^3.

(c) Cement contents in excess of 500 kg/m^3 should generally not be used.

5.16 Water/cement ratio

5.16.1 The concrete should have an effective water/cement ratio not greater than 0,45. In the splash zone and in the boundaries of oil storage tanks this ratio should not be higher than 0,40; this also applies to areas that can be exposed to severe frost action.

5.17 Minimum concrete strength

5.17.1 For concrete exposed to sea water and stored oil, the characteristic cylinder strength at 28 days should not be less than 40 MPa.

5.18 Temperature

5.18.1 The requirements of ISO 19903 or an alternative agreed reference standard should be followed with respect to temperature limitations applicable to different aspects of concrete construction:

(a) Bar bending;

(b) Concrete casting and curing;

(c) Post-tensioning;

(d) Procedures should be developed and agreed for hot weather and cold weather concreting.

5.19 Freezing and thawing

5.19.1 Parts of the structure that are subjected to freezing and thawing are to have adequate frost resistance. For severe situations, air entrainment may be used. In such cases reference should be made to relevant standards for details of quality of air and spacing factors.

5.20 Concrete cover

5.20.1 The following is the minimum required concrete cover to reinforcement:

(a) 50 mm in the splash zone;

(b) 40 mm elsewhere outside the splash zone.

5.20.2 For pre-stressing tendons, a minimum of 90 mm is required. These are minimum values. Permitted tolerance (negative deviation) on the position of reinforcement should be added to give the nominal cover.

5.21 Concrete protection against chemical attack

5.21.1 For oil storage tanks, the possible attack by hydrogen sulphide, organic acids, etc. is to be considered.

5.21.2 Where flue gases are used as the inerting medium in tanks, consideration is to be given to the concrete being attacked by CO2 and/or SO2 in hot, high humidity conditions. This will need to be addressed on a case-by-case basis.

5.21.3 Where sufficiently high concentrations of chemicals may occur which could result in chemical attack, consideration is to be given to providing a suitable chemical-resistant liner or partial liner.

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Section
1 **General requirements for corrosion control**

2 **Cathodic protection systems**

3 **Coating and paint systems**

4 **Guidance notes on design of cathodic protection systems and coatings**

Section 1
General requirements for corrosion control

1.1 Application

1.1.1 All structural steelwork is to be suitably protected against loss of integrity due to the effects of corrosion. Suitable protective systems may include coatings, metallic claddings, cathodic protection, corrosion allowances or other approved methods. Combinations of methods may be used. Consideration should be paid to the design life and the maintainability of the surfaces in the design of the protective systems. Special consideration will be given to the corrosion protection of floating fixed installations.

1.2 Zone definitions

1.2.1 The type of protection is to be suitable for the intended location and for this purpose the steel structure should be considered in terms of zones:

- Submerged zone: That part of the external structure below the splash zone.
- Splash zone: That part of the external structure between a level 2 m above Mean High Water Springs (MHWS) and a level 3 m below the Lowest Astronomical Tide (LAT).
- Atmospheric zone: That part of the external structure above the splash zone.
- Internal zones: Closed flooded compartments, free flooding compartments, and storage tanks and other compartments.

1.3 External zone protection

1.3.1 Steelwork in the splash zone is to be protected by one or more of the following:

(a) Extra steel in excess of that needed for strength;
(b) Metallic cladding;
(c) Coatings.

1.3.2 Steelwork in the atmospheric zone is to be protected by suitable coatings.

1.3.3 Steelwork in the submerged zone is to be protected by an approved means of cathodic protection using sacrificial anodes with or without an impressed current system. High duty coatings may be used in conjunction.

1.3.4 Coatings are not normally to be applied to piles, but partial coating of the top sea water-exposed external surface may be provided to reduce current demand on the cathodic protection system.

1.4 Compartments

1.4.1 Closed flooded compartments may be protected by one or more of the following:

(a) Extra steel in excess of that needed for strength;
(b) Coatings;
(c) Cathodic protection;
(d) Corrosion inhibitors together with biocides;
(e) Chemicals for pH control together with biocides.

1.4.2 Free flooding compartments are to be avoided as far as possible. Any which cannot be avoided are to be protected by one or more of the following:

(a) Extra steel in excess of that needed for strength;

(b) Coatings;
(c) Cathodic protection.

1.4.3 Storage tanks and other compartments require corrosion protection where the stored product may be corrosive. Particular attention should be paid to the likelihood of water being present in the bottom of hydrocarbon storage tanks and the effects of bacterial induced corrosion. Suitable protective measures are as detailed for closed flooded compartments.

1.5 Plans and information

1.5.1 In order that an assessment may be made of protection systems, full details as outlined in this sub-Section are to be submitted.

1.5.2 **Cathodic protection systems.** The following plans and information are to be submitted:

(a) A surface area breakdown for all areas to be protected (sea water-immersed and buried), including secondary steelwork and details of temporary appurtenances.
(b) The resistivity of the sea water and sediments.
(c) All current densities used for design purposes.
(d) The type and location of any reference electrodes, their methods of attachment and the method for transmitting the potential data.
(e) Full details of any coatings used and the areas to which they are to be applied.
(f) Details of any electrical bonding, e.g. piles to pile sleeves or jacket legs or insulation.
(g) Details of current drain.
(h) Stray current considerations.

1.5.3 **Sacrificial anode systems**. In addition to the information required by *Ch 6, 1.5 Plans and information 1.5.2*, the following plans and information are to be submitted:

(a) The design life of the system, in years.
(b) Anode material and minimum design capacity of anode material, in Ah/kg.
(c) The dimensions of anodes including details of the insert and its location.
(d) The net and gross weight of the anodes, in kg.
(e) The means of attachment.
(f) Plans showing the location of the anodes.
(g) Calculation of anodic resistance, as installed and when consumed to their design utilisation factor, in ohms.
(h) Closed circuit potential of the anode material, in volts.
(i) Details of any computer modelling.
(j) The anode design utilisation factor.

1.5.4 **Impressed current systems.** In addition to the information required by *Ch 6, 1.5 Plans and information 1.5.2*, the following plans and information are to be submitted:

(a) The anode composition and, where applicable, the thickness of the plated surface, consumption and life data.
(b) Anode resistance, limiting potential and current output.
(c) Details of construction and attachment of anodes and reference electrodes.
(d) Size, shape and composition of any dielectric shields.
(e) Diagram of the wiring system used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in circuits, and the capacity, type and make of the protected devices.
(f) Details of glands and size of steel conduits.
(g) Plans showing the locations of the anodes and reference electrodes.
(h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

1.5.5 **Coating systems**. The following plans and information are to be submitted:

(a) Evidence that any primers used will have no deleterious effect on subsequent welding or on subsequent coatings.
(b) Details of the painting specification with regards to:
    (i) The generic type of the coating and confirmation of its suitability for the intended environment;

(ii) The methods to be used to prepare the surface before the coating is applied and the standard to be achieved.
(iii) Established International or National Standards;
(iv) The method of application of the coating;
(v) The number of coats to be applied and the total dry film thickness;
(vi) The areas to be coated;
(vii) An Inspection and Testing Plan. In addition to the information required by *Ch 6, 1.5 Plans and information 1.5.5.(a)*, the following may also be required:

(c) When a coating contains aluminium and is intended to be used on decks or in areas where flammable gases may accumulate, a statement from an independent laboratory confirming that appropriate tests have shown that the coating does not increase the incendive sparking hazard in the area to which it is to be applied.

(d) Where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire risk, a statement that the coating is not formulated on a nitrocellulose or other highly flammable base and has low flame spread characteristics (complying to at least BS 476: Part 7: Classification 2 or any other equivalent National Specification).

1.5.6 Inhibitors and biocides. Where it is proposed to use inhibitors, biocides or other chemicals for the protection of closed flooded compartments, full details, including of compatibility with each other and evidence of satisfactory service experience or suitable laboratory test results or any other data to substantiate the suitability for the intended purpose, are to be submitted for consideration.

Section 2
Cathodic protection systems

2.1 Objective

2.1.1 The cathodic protection system for the external submerged zone is to be designed for a period commensurate with the service life of the structure and it should be capable of polarising the steelwork to a sufficient level in order to minimise corrosion at any point in the service life.

2.1.2 This may be achieved using either sacrificial anodes or an impressed current system or a combination of both, *see Ch 6, 2.18 Protection during platform installation*.

2.2 Electrical continuity

2.2.1 All parts of the structure should be electrically continuous and, where considered necessary, appropriate bonding straps should be fitted across such items as piles and pile sleeves or jacket legs, and the joints of articulated structures are to be efficiently completed to the Surveyor's satisfaction.

2.2.2 Where bonding straps are not fitted, a supplementary cathodic protection system should be considered.

2.2.3 Particular attention to earthing and bonding is required in hazardous areas where flammable gases or vapours may be present, *see Ch 7, 6 Electrical and instrumentation systems* and *Ch 8 Fire and Safety Equipment*.

2.2.4 To avoid dangerous sparking between metallic parts of structures, potential equalisation is always required for installations in Zone 1 and may be necessary for installations in Zone 2 areas; this is achieved by connecting all exposed and extraneous conductive parts to the equipotential bonding system. Notwithstanding this, cathodic protection installations are not to be connected to the equipotential bonding system unless the cathodic protection system is specifically designed for this purpose. *See* IEC 61892-7 Section 5.6.3.

2.2.5 Cathodically protected metallic parts are live extraneous conductive parts. If located in hazardous areas, they are to be considered potentially dangerous (especially if equipped with the impressed current method) despite their low negative potential.

2.2.6 No cathodic protection is to be provided for metallic parts in Zone 0 unless it is specially designed for this application. *See* IEC 61892-7 Section 5.6.6.

2.2.7 Consideration should be given to the influence of any connecting structures, such as risers and pipelines, on the efficiency of the cathodic protection system. A floating structure may be permanently or temporarily connected to another neighbouring structure.

2.3 Criteria for cathodic protection

2.3.1 Cathodic protection systems are to comply with BS EN 12495 unless local legislation requirements dictate otherwise; replacement standards shall be listed and submitted to LR for approval.

2.3.2 The cathodic protection system is to be capable of polarising the steelwork to potentials measured with respect to a silver/silver chloride/sea-water (Ag/AgCl) reference electrode to within the following ranges:

(a) –0,80 to –1,10 volts for aerobic conditions;

(b) –0,9 to –1,10 volts for anaerobic conditions.

2.3.3 Potentials more negative than –1,10 volts Ag/AgCl must be avoided in order to minimise any damage due to hydrogen absorption and reduction in the fatigue life. For steel with a tensile strength in excess of 700 N/mm^2 the maximum negative potential should be limited to –0,95 volt. But where the steel is prone to hydrogen assisted cracking the potential should not be more negative than –0,83 volt (Ag/AgCl reference cell).

2.3.4 High strength fastening materials should be avoided because of the possible effects of hydrogen, and the hardness of such bolting materials should be limited to a maximum Vickers Diamond Pyramid Number of 300 or equivalent.

2.3.5 The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

2.3.6 For guidance on the design of sacrificial anode systems, *see Ch 6, 4.2 Sacrificial anode systems*.

2.4 Sacrificial anodes

2.4.1 Sacrificial anodes intended for installation on fixed offshore structures are to be manufactured in accordance with the requirements of *Ch 6, 2.4 Sacrificial anodes* to *Ch 6, 2.16 Anode installation*.

2.4.2 Plans showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to manufacture.

2.4.3 Approval for the manufacture of anodes is not required, although the anodes should preferably be type approved in accordance with Lloyd's Register's (LR's) List of Type Approval Equipment.

2.4.4 The works should have a quality management system certified by a recognised third-party certification body. However, alternative arrangements may be accepted provided they ensure a consistent quality for the anodes.

2.5 Anode materials

2.5.1 The anode materials are to be approved alloys of zinc or aluminium. A closed-circuit potential more negative than –1,00 volt (Ag/AgCl reference electrode) for zinc anodes and –1,05 volt (Ag/AgCl reference electrode) for aluminium anodes shall be achieved in sea water at ambient temperature up to 30°C. Magnesium-based anodes may be used for short-term temporary protection of materials not susceptible to hydrogen embrittlement, *see also Ch 6, 2.16 Anode installation 2.16.12*. Anode materials and anode designs specified in BS EN 12495 are also permitted.

2.6 Steel insert preparation

2.6.1 The anode material is to be cast around a steel insert so designed as to retain the anode material even when it is consumed to its design utilisation factor.

2.6.2 The steel inserts are to have sufficient strength to withstand all external forces that they may normally encounter such as piling operations and wave, wind and ice loading.

2.6.3 The anodes are to be sufficiently rigid to avoid vibration in the anode support.

2.6.4 The steel inserts are to be of weldable structural steel bar, section or pipe with a carbon equivalent not greater than 0,45 per cent determined using the following formula:

$$\text{Carbon equivalent, } C_{eq} = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15$$

2.6.5 Rimming steel is not permitted.

2.6.6 Requirements for welded fabrication and non-destructive testing are to be in accordance with *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

2.6.7 The steel insert is to be degreased if necessary and blast cleaned to a standard equivalent to ISO 8501-1 Sa21/2 with a minimum surface profile of 50 µm. This standard of cleanliness is to be maintained up until the time of castings. For zinc anodes, blast cleaning may be followed by galvanising or by an approved zinc plating process.

2.7 Chemical composition

2.7.1 The chemical composition of the heat is to be determined prior to casting. No alloying additions are to be made following chemical analysis without further analysis. For heats greater than one tonne, a further sample is to be analysed at the end of the cast. All anodes cast are to comply with the approved specification. Typical chemical compositions for Al-Zn-In type and zinc type anodes which are known to perform well in many conditions are shown in *Table 6.2.1 Aluminium anode composition* and *Table 6.2.2 Zinc anode composition*. Other compositions may be used if testing demonstrates that the required electrochemical properties can be achieved. Any testing shall be submitted to LR for approval.

Table 6.2.1 Aluminium anode composition

Element	Mass Fraction (w)	
	Min %	Max %
Zn	2,5	5,75
In	0,016	0,040
Fe	–	0,09
Si	–	0,12
Cu	–	0,003
Cd	–	0,002
Others	–	0,02 (each)
Al	Remainder	

Table 6.2.2 Zinc anode composition

Element	Mass Fraction (w)	
	Min %	Max %
Cu	2,5	0,005
Al	0,016	0,50
Fe	–	0,005
Cd	–	0,07
Pb	–	0,006
Zn	Remainder	

2.8 Conditions of supply

2.8.1 Generally, anodes are to be supplied in the as-cast condition although certain aluminium anodes may be heat-treated in accordance with the approved specification.

2.8.2 Where heat treatment is carried out it is to be in properly constructed furnaces which are efficiently maintained and have adequate means for the control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature.

2.9 Anode identification

2.9.1 The manufacturer is to adopt a system of identification of the anodes to enable the material to be traced back to its original cast.

2.9.2 The anodes are to be clearly marked with the following:

(a) Name or initials of the anode manufacturer;
(b) Number and/or initials to identify the batch;
(c) Agreed identification mark for the anode material.

2.9.3 Where the anodes are heat-treated they are also to be marked with the appropriate heat treatment batch number.

2.10 Anode inspection

2.10.1 All anodes are to be cleaned and adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. However, any flash or other protrusions should be removed prior to inspection.

2.10.2 Anodes are to be inspected prior to the application of any coating which may be applied to the underside of the anode or to the exposed steelwork.

2.10.3 The surface should be free of any significant slag or dross or anything that may be considered detrimental to the satisfactory performance of the anodes.

2.10.4 Shrinkage depressions should not exceed 10 per cent of the nominal depth of the anode or 50 per cent of the depth to the anode insert, whichever is the smaller.

2.10.5 Cracks in the longitudinal direction are not acceptable. Small transverse cracks may be permitted provided:

(a) They are not more than 5 mm in width;
(b) They are within the section wholly supported by the steel insert;
(c) They do not extend around more than two faces or 180° of the anode circumference; and,
(d) The Surveyor is satisfied that there has been no breakdown in quality control procedures.

2.10.6 Cold shuts or surface laps should not exceed a depth of 10 mm or extend over a total length equivalent to more than three times the width of the anode. All material is to be completely bonded to the bulk material.

2.11 Dimensions

2.11.1 The accuracy and verification of dimensions is the responsibility of the manufacturer unless otherwise agreed.

2.11.2 The diameter of cylindrical anodes should be within ±5 per cent of the nominal diameter.

2.11.3 For long, slender anodes the following dimensions should apply:

- Mean length ±3 per cent of nominal length or ±25 mm, whichever is smaller;
- Mean width ±5 per cent of nominal width;
- Mean depth ±10 per cent of nominal depth.

2.11.4 The maximum deviation from straightness should not exceed two per cent of the length.

2.11.5 The steel insert should be within ±5 per cent of the nominal position in anode width and length and within 10 per cent of the nominal position in depth. Some anodes may have the insert close to one surface, in which case a closer tolerance may be more appropriate.

2.11.6 Except where previously agreed, the anode insert fixing dimensions are to be within ±1 per cent of the nominal dimensions or 15 mm, whichever is the smaller.

2.11.7 Anode nominal dimensions, tolerances and fabrication details are to be shown on manufacturing plans prepared by the manufacturer and submitted for approval, *see Ch 6, 2.4 Sacrificial anodes 2.4.2*.

2.12 Anode weight

2.12.1 Anodes are to be weighed and individual anodes should be within ±5 per cent of the nominal weight for anodes less than 50 kg or ±3 per cent of the nominal weight for anodes 50 kg and over.

2.12.2 No negative tolerance is permitted on the total contract weight and the positive tolerance should be limited to two per cent of the nominal contract weight.

2.13 Bonding and internal defects

2.13.1 It will be necessary for the manufacturer to demonstrate that there is a satisfactory bond between the anode material and the steel insert and that there are no significant internal defects. This may be carried out by sectioning of an anode selected at random from the batch or by other approved means.

2.13.2 Where sectioning is carried out, at least one anode or at least 0,5 per cent of each production run is to be sectioned transversely at 25 per cent, 33 per cent and 50 per cent of the nominal length of the anode or at other agreed locations for a particular anode design.

2.13.3 The cut surfaces are to be essentially free from slag or dross.

2.13.4 Small isolated gas holes and porosity may be accepted provided their surface area is not greater than two per cent of the section.

2.13.5 No section is to show more than ten per cent lack of bond between the insert and the anode material.

2.14 Electrochemical testing

2.14.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as-cast electrochemical properties.

2.15 Certification

2.15.1 The manufacturer is to provide copies of the Material Certificate or shipping statement for all acceptable anodes.

2.15.2 The certificate is to include at least the following information:

(a) Name of manufacturer;
(b) Description of anode, alloy designation or trade name;
(c) Cast identification number;
(d) Chemical composition;
(e) Details of heat treatment where applicable;
(f) Results of electrochemical test;
(g) Weight data;
(h) Purchaser's name and order number, and the name of the structure for which the material is intended.

2.15.3 The manufacturer is to confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and the RP.

2.16 Anode installation

2.16.1 The location and means of attachment of anodes are to be submitted for approval.

2.16.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.16.3 Where bracelet anodes are proposed, the tightness of the anodes is not to rely on the anode material being in direct contact with the structure.

2.16.4 The location and attachment of anodes are to take account of the stresses in the members concerned, including those induced by pile driving and conductor installation. Anodes are not to be directly attached to the primary bracings.

2.16.5 The anode supports may be welded directly to the structure in low-stress regions provided they are not attached in way of butts, seams, nodes or any stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.16.6 The attachment of all anodes to primary bracing members and nodes is to be submitted for approval. Anodes are not to be welded directly to the structure and the supports are to be welded to small doubler plates which are attached by continuous welds to the structure.

2.16.7 All welding is to be carried out by qualified welders using a qualified welding procedure in accordance with *Ch 12 Welding Qualifications* and *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

2.16.8 The welds are to be examined using magnetic particle inspection or other acceptable means of non-destructive testing in accordance with *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2022*.

2.16.9 Anodes attached to studs 'fired' into the structure are not permitted.

2.16.10 The anodes are to be located on the structure to ensure rapid polarisation of highly stressed areas such as node welds and with due regard to a possible reduction in throwing power in re-entrant angles.

2.16.11 Anodes should not be located in positions where they may be damaged by craft coming alongside.

2.16.12 Magnesium anodes are not to be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted, *see Ch 6, 2.5 Anode materials 2.5.1*.

2.17 Impressed current anode systems

2.17.1 Impressed current anode materials may be of lead-silver alloy or platinum over such substrates as titanium, niobium, tantalum, or of mixed oxides-activated titanium. Anode materials and anode designs specified in BS EN 12495 are also permitted.

2.17.2 The design and installation of electrical equipment and cables is to be in accordance with the requirements of *Ch 7, 6 Electrical and instrumentation systems*.

2.17.3 If hazardous areas are present on the facility, the impressed current cathodic protection system and equipment are to comply with the requirements of:

- *Ch 7, 6 Electrical and instrumentation systems* (in particular Ch 7, 6.10 Supply and distribution),
- *Ch 8, 2.9 Electrical equipment for use in explosive gas atmospheres*,
- *Ch 8, 2.10 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*,
- *Ch 8, 2.11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes*,
- IEC 60079 series, and
- IEC 60092-502.

2.17.4 IEC 60092-502 Clause 5.7 'Cathodically protected metallic parts' states 'No impressed current cathodic protection shall be provided for metallic parts in hazardous areas, unless it is specially designed for this application and acceptable to the appropriate authority'.

2.17.5 The insulating elements required for the cathodic protection – for example, insulating elements in pipes and tracks – should if possible be located outside the hazardous area. *See* IEC 61892-7 Section 5.6.6.

2.17.6 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the storage of low flashpoint oils. Where cables are led through cofferdams of oil storage units, they are to be enclosed in a substantial steel tube of about 10 mm thickness.

2.17.7 The arrangement for glands, where cables pass through shell boundaries, are to include a small cofferdam.

2.17.8 Cable and insulating materials should be resistant to chloride, hydrocarbons and any other chemicals with which they may come into contact.

2.17.9 Where the power is derived from a rectified a.c. source, adequate protection is to be provided to trip the supply in the event of a fault between the input or high voltage windings of the transformer (i.e. main voltage) and the d.c. output of the associated rectifier; or the ripple on the rectified d.c. exceeding five per cent. The requirements for transformers and semi-conductor equipment are given in *Ch 7, 6.25 Rotating machines*.

2.17.10 Anodes may be installed in the following locations and by the following methods provided the general requirements given in *Ch 6, 2.16 Anode installation* regarding attachments to the structure are complied with:

(a) By mounting in insulating holders attached directly to the submerged structural member;
(b) By mounting in insulating holders attached directly to the submerged platform member;
(c) By mounting on additional steelwork attached to the platform members;
(d) By suspending from suitable cables;
(e) By being attached to suitable sleds on the seabed.

2.17.11 Where groundbeds are located away from the structure, consideration should be given to possible interaction with risers or pipelines.

2.17.12 Suitable dielectric shields are to be fitted in order to avoid high negative potentials.

2.17.13 A warning light or other warning indicator is to be arranged at the control position from which divers are controlled to indicate that the impressed current cathodic protection system has been switched off when divers are in the water.

2.18 Protection during platform installation

2.18.1 Where protection is primarily by an impressed current cathodic protection system, sufficient sacrificial anodes are to be fitted, capable of polarising the critical regions of the structure from the time of initial immersion until full commissioning of the impressed current system.

2.19 Fixed potential monitoring systems

2.19.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system, and, although not essential, such a monitoring system is recommended for use in conjunction with sacrificial anodes. Monitoring schemes shall comply with BS EN 13509.

2.19.2 Zinc or Ag/AgCl reference electrodes should be used. Reference electrode materials and design specified in BS EN 13509.

2.19.3 Variations between electrodes of ±30 mV have been reported for zinc/sea-water reference electrodes and ±5 mV for Ag/AgCl/sea-water electrodes, but unless a high degree of stability is required, either electrode may be used for comparison purposes. The zinc/sea-water electrode may be taken as approximately 1,03 V more positive than the silver/silver chloride/sea-water electrode.

2.19.4 The location and attachment of the reference electrodes are to take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any stress raisers.

2.19.5 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

2.19.6 The reference electrodes may be connected to the topsides display and control equipment by suitable cabling or by any other agreed means.

2.19.7 Provision is to be made for the regular recording at an agreed interval of the potential of the steelwork, and log sheets are to be made available for inspection when required by LR Surveyors.

2.20 Cathodic protection in tanks

2.20.1 Impressed current cathodic protection systems are not to be fitted in any tank.

2.21 Sacrificial anodes

2.21.1 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other flammable vapour, in relation to both the structural arrangements and the openings of the tanks.

2.21.2 Aluminium and aluminium alloy anodes are permitted in tanks that may contain explosive or flammable vapour, but only at locations where the potential energy of the anode does not exceed 275 J. The weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. The height is to be taken as the distance from the bottom of the tank to the centre of the anode but exception to this may be given where the anodes are located on wide horizontal surfaces from which they cannot fall.

2.21.3 Aluminium anodes are not to be located under tank hatches or other openings unless protected by adjacent structure.

2.21.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast, in which case adequate venting must be provided.

2.21.5 Anodes fitted internally should preferably be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding at least 25 mm away from the edge of the web.

2.21.6 In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the mild steel face-plate but well clear of the free edges. Where higher tensile steel face-plates are fitted, the anodes are to be attached to the webs.

2.21.7 Anodes are not to be attached directly to columns or primary bracings.

2.21.8 For guidance on the design of sacrificial anode systems in tanks, *see Ch 6, 4.4 Protection of tanks*.

2.22 Potential surveys

2.22.1 Potential surveys of the external submerged zones are to be carried out at agreed intervals.

2.22.2 Should the results of any potential survey measured with respect to an Ag/AgCl reference cell indicate values more positive than –0,8 volt for aerobic conditions or –0,9 volt for anaerobic conditions then remedial action such as retrofit of sacrificial anode or adjustment and maintenance of ICCP system is to be carried out at the earliest opportunity.

2.23 Retrofits

2.23.1 Where it is proposed to fit additional anodes or replace existing ones, full details including the information listed below are to be submitted for consideration:

(a) Existing CP system performance study;
(b) Cause of any premature failure of the system;
(c) Design calculations and drawings;
(d) CP potential modelling;
(e) Deviations from class requirements based on in-service performance on station.

2.23.2 Where it is necessary to weld anodes to the structure, only approved welding procedures and consumables are to be used, in accordance with *Ch 12 Welding Qualifications* and *Ch 13 Requirements for Welded Construction* of the .

Section 3
Coating and paint systems

3.1 General requirements

3.1.1 The painting specification is to be submitted for approval, *see Ch 6, 1.5 Plans and information 1.5.5.(a)*.

3.1.2 Paints, varnishes and similar preparations having nitrocellulose or any other highly flammable base are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire risk.

3.1.3 Where a coating is to be applied in accommodation spaces and areas of similar fire risk, the coating is to have low flame spread characteristics, *see Ch 6, 1.5 Plans and information 1.5.5.(b)*.

3.1.4 Paints or other similar coatings containing greater than ten per cent aluminium by weight in dry film should not be used in positions where flammable vapours may accumulate unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

3.1.5 Any sheathing or composition to protect decks is to be applied in such a manner that corrosion will not occur unseen beneath the covering.

3.1.6 Deck coatings or coverings used on decks forming the crown of spaces with a high fire risk (such as helidecks, machinery and accommodation spaces) or which are within accommodation spaces, control rooms, emergency escape routes, etc. are to be of a type which will not readily ignite, *see Ch 6, 1.5 Plans and information 1.5.5.(b)*.

3.1.7 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used.

3.1.8 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of ISO 8501-1 Sa2½. All resulting dust is to be removed from the surface prior to the application of any paint.

3.1.9 Maintenance of the protective coating systems is to be included in the unit's overall maintenance scheme.

3.2 Prefabrication primers

3.2.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

3.2.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in Sections 3.2.1.3 to 3.2.1.5 of LR's List of Paint Resins, Reinforcements and Associated Materials.

3.2.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A vee preparation is to be used and, prior to welding, the surfaces and edges are to be treated as follows:

(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

3.2.4 Tests as follows are to be taken from each test assembly:

(a) Radiographs. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) Photo-macrographs. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) Face and reverse bend test. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.

(d) Impact tests. Tests are to be carried out, at ambient temperature, on three Charpy V-notch test specimens prepared in accordance with the requirements of the Rules for the Manufacture, Testing and Certification of Materials. The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

3.2.5 The tests are to be carried out in the presence of an LR Surveyor or by an independent laboratory specialising in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

■ *Section 4*
Guidance notes on design of cathodic protection systems and coatings

4.1 Current density

4.1.1 The current density required for the external protection of the submerged zone of units will depend on many factors such as water temperature, oxygen content, resistivity of the water, suspended solids, water currents and biological activity.

4.1.2 Design current density values are given in *Table 6.4.1 Current density values for design purposes* for guidance purposes, but the values to be used should be based on the environmental conditions prevailing at the site. It should be noted that these values may be appreciably different from values actually measured on steelwork in the vicinity of the site.

Table 6.4.1 Current density values for design purposes

Location	Current density mA/m^2		
	Initial	Mean	Final
Cook inlet	400	400	400
North sea (Northern) above 62ºN	220	100	130
55ºN to 62ºN	180	90	120
North Sea (Southern) below 55ºN	150	80	100
Arabian Gulf, Africa, Brazil, China, India	130	70	90
Mediterranean, Australia (Western), Gulf of Mexico, Adriatic Sea, US West Coast	110	60	80
Mud – Most locations	25	20	20
Drainage per well	5A		

Note 1. The current density values are intended for guidance purposes in the design of sacrificial anode systems using the methods as outlined in this Chapter. However, other values may be accepted provided that there is adequate justification.

Note 2. For impressed current cathodic protection systems, current densities higher than the values given in this Table may be necessary but this will depend on the type, location and quantity of the anodes.

4.1.3 In order to minimise pitting, the cathodic protection system must be capable of rapidly polarising the steelwork and the cathodic protection design must demonstrate that the system is capable of initially polarising the structure rapidly in order to minimise pitting.

4.1.4 The cathodic protection system must be capable of re-polarising the steelwork rapidly after storms, even when the anodes are well wasted; this should be demonstrated in design calculations.

4.1.5 Where suitable high resistance coatings are used, consideration will be given to use of current densities lower than those given in *Ch 6, 4.1 Current density 4.1.2*.

4.1.6 Coatings will deteriorate with time and there is likely to be mechanical damage. In order to take this into account at the design stage, appropriate coating breakdown factors should be applied and these are to be based on the percentages given in *Ch 6, 4.1 Current density 4.1.7* and *Ch 6, 4.1 Current density 4.1.8*.

4.1.7 For an epoxy or coal tar epoxy coating applied to give a dry film thickness of 250 to 500 microns, an initial coating breakdown factor of one to two per cent for the submerged zone and an annual degradation rate of one to one and a half per cent per year should be used, in line with BS EN 12495, unless agreed otherwise by the Owner. Coating breakdown factors for high build coatings, applied to give a dry film thickness of 1000 to 3000 microns, should be lower and be agreed by the Owner.

4.1.8 For other coating systems an initial breakdown factor of a minimum of five per cent should be used and added to any area that is visibly damaged. Due allowance should be made for further breakdown during the service life as given in *Ch 6, 4.1 Current density 4.1.7*.

4.1.9 Current drain due to risers, piles and other electrically connected structures shall be considered in the current requirement calculations and be fully documented.

4.2 Sacrificial anode systems

4.2.1 The following indicates an acceptable method for determining the number and weight of anodes to achieve the required level of polarisation on most structures. Other methods may be accepted provided they give reasonable equivalence.

4.2.2 The type of anode selected must be of sufficient mass with appropriate dimensions to ensure an adequate current output throughout its design life.

4.2.3 The current output of the anode should be calculated using the following formula:

$$I_a = \frac{\Delta V}{R_a}$$

where

I_a = current output of anode, in amps

ΔV = driving potential, i.e. the difference between the potential of the anode and the protected steel potential, in volts

R_a = anodic resistance, in ohms

4.2.4 The potential of the polarised steel should be taken as –0,8 volt (Ag/AgCl /sea-water reference electrode), although a more negative value may be used for those locations where sulphate-reducing bacteria may be active, *see Ch 6, 2.3 Criteria for cathodic protection*.

4.2.5 The resistance of an anode, R, with small cross-section in relation to its length ($4r \leq L$) and with a stand-off distance from the bottom of the anode surface to the structure of not less than 300 mm, is given by:

(a) $$R = \frac{r}{2\pi l_a}\left(\ln\frac{4l_a}{\rho} - 1\right)$$

where

ρ = resistivity of sea water, in ohm.cm

l_a = length of anode, in cm

r = equivalent radius of anode, in cm

$\ln$ = $\log_e$

a = cross-sectional area of the anode, in cm^2

(b) When bracelet anodes are used, the resistance may be determined using:

$$R = \frac{0,315\rho}{\sqrt{A_e}}$$

where

A_e = the exposed surface area of the anode, in cm^2

4.2.6 In order to achieve a suitable anode distribution on tubular structures, each appropriate section of steelwork should be considered separately.

4.2.7 The current required for each section may be determined from the following:

$$I_r = \frac{AI}{1000} r = \sqrt{\frac{a}{k}}$$

where

I_r = current, in amps

A = area of steelwork, in m^2

I = current density, in mA/m^2

The number of anodes, N, required should satisfy both of the following:

$$N = \frac{I_r}{I_a}$$

$$N = \frac{W_r}{W_a}$$

where

I_r = current, in amps

I_a = current output of anode, in amps

W_r = net weight of anode material, in kg

W_a = net weight of individual anode, in kg

$$W_r = \frac{I_r Y 8760}{CU}$$

Y = life of structure in years, *see Ch 6, 2.1 Objective 2.1.1*

C = practical electrochemical capacity of the alloy, in Ah/kg

U = utilisation factor, i.e. proportion of net weight consumed at end of anode life. For fully

supported tubular inserts

U = 0,9

U = 0,8 for bracelet (half shell)

U = 0,75 for bracelet (segmental type).

In order to optimise the performance and efficiency of the anodes the values obtained from both equations should be similar.

4.2.8 It is to be shown by appropriate calculations that the system is capable of polarising the structure initially and also when the anodes are consumed to their design utilisation factor.

4.2.9 It should be assumed that, at the end of its life, the anode length has been reduced by ten per cent and that the remaining material is evenly distributed over the steel insert.

4.3 Location of anodes

4.3.1 Having determined the number and size of the anodes to comply with the recommended nominal current density and the required life, the anodes should be distributed over the steel surfaces according to the required level of protection on the steelwork but with some emphasis on the areas adjacent to joints, etc. CP potential modelling can be considered to aid distribution to ensure full coverage. The anodes associated with the structure likely to become buried, such as footings, etc., should be positioned on the steelwork immediately above the mudline.

4.4 Protection of tanks

4.4.1 Where large stand-off anodes are used for the protection of tanks, the resistance should be determined using the formula as given in *Ch 6, 4.2 Sacrificial anode systems 4.2.5*.

4.4.2 Where flat plate anodes are used, their resistance is to be determined from the following formula:

$$R = \frac{\rho}{4l_m}$$

however, if the flat plate anodes are close to the structure or painted on the lower face then the resistance is to be determined using:

$$R = \frac{\rho}{2l_m}$$

where ρ is as defined in *Ch 6, 4.2 Sacrificial anode systems 4.2.5*.

l_m = mean length of anode sides, in cm

4.4.3 The design current density to be used for permanent water ballast tanks should be based on a minimum value of 110 mA/m^2 but this may have to be increased to at least 130 mA/m^2 if hot oil is stored on the opposite side of the bulkhead. For a coating allowance, *see Ch 6, 4.1 Current density 4.1.6*.

4.4.4 Uncoated tanks used for the storage of crude oil at ambient temperature alternating with water ballast are to have a minimum current density of 90 mA/m2; however, this should be increased for higher temperatures.

4.4.5 Unless otherwise agreed, the resistivity of the water in ballast tanks should be assumed to be 25 ohm.cm.

4.4.6 Once the number and size of anodes have been determined, the anodes are to be distributed as follows:

(a) Ballast-only tanks: evenly over all the steelwork with some consideration given to the lower sections based on usage pattern and ballasting levels.

(b) Crude oil/ballast tanks: evenly but with some emphasis on horizontal surfaces in proportion to the area of these surfaces.

4.5 Surface preparation and the application and maintenance of coatings

4.5.1 These notes have been prepared to give general guidance on those aspects of surface preparation and the application and subsequent maintenance of coatings that should be taken into account by those agreeing the coating specification.

4.5.2 These notes are not intended to be used for contractual purposes or as representing the minimum requirements as these are a matter for the interested parties to agree.

4.5.3 The guidelines do not intend to replace the technical aspects of any specific coating system, to be covered by the product and job specifications, which are at the discretion and under the responsibility of Owners, manufacturers and construction yards.

4.5.4 Owners should select and maintain a corrosion protection system to ensure an adequate level of protection.

4.5.5 Coating manufacturers should give evidence of the quality of the product and its ability to satisfy the Owner's requirements.

4.5.6 Coating manufacturers should have products with documented service performance records. Coatings recognised by LR are considered as satisfying this requirement, see the list of LR approved PSPC compliant coatings on Class Direct. Where it is proposed to use coatings without satisfactory performance records, coating selection should be supported by appropriate laboratory test data carried out in accordance with recognised Standards (e.g. ISO 20340) in order to verify their suitability for the intended service condition.

4.5.7 The construction yard and/or its sub-contractors should provide clear evidence of their experience in coating application. The coating standard, job specification, inspection, maintenance and repair criteria should be agreed by the construction yard and/or its sub-contractors, Owner and manufacturer.

4.5.8 At present, hard coatings are the most commonly used for new construction.

4.5.9 As their effectiveness and life are influenced by several factors, it is essential that the manufacturer's technical product datasheet and job specifications are followed.

4.5.10 Multi-coat applications with coating layers of contrasting colours are recommended. The last coating layer in ballast tanks should be of a light colour in order to facilitate in-service inspections.

4.5.11 Measures should be adopted at the design stage to reduce scallops, use rolled profiles (provided this does not adversely affect fatigue performance) or three-pass grinding where possible and ensure that the structural configuration permits easy access for personnel and equipment and facilitates cleaning, draining and drying of tanks.

4.5.12 Where a coating is supplemented by cathodic protection, the coating must be compatible with the cathodic protection system.

4.6 Coating selection

4.6.1 In the selection of a coating for use in ballast tanks, the following should be taken into account:

- Service conditions and planned maintenance;
- Frequency of ballasting/deballasting operations;
- Location of tank relative to heated surfaces;
- Required surface condition;
- Required surface cleanliness and dryness;
- Whether cathodic protection is to be fitted.

4.6.2 Coatings intended for use underneath solar heated decks or on bulkheads forming boundaries of heated cargo or fuel oil spaces should be able to withstand constant or repeated heating without becoming brittle or subject to a loss of adhesion. Due regard should be given to the possible poor edge-covering properties of hard coatings with a high solid content.

4.7 Initial preparation

4.7.1 Tubular scaffolding should not mask surfaces to be coated. Where contact is necessary, spade ends should be used.

4.7.2 Staging should afford easy and safe access to all surfaces to be coated.

4.7.3 Tubular scaffolding should be plugged or capped prior to blast cleaning to prevent the ingress of grit and dirt.

4.7.4 Staging should be designed to allow thorough cleaning.

4.7.5 Staging layout should be such that ventilation is not rendered ineffective.

4.7.6 Care should be taken when removing scaffolding in order to keep damages to a minimum. Any damages should be repaired in accordance with the paint manufacturer's recommendations.

4.7.7 External surfaces of pipelines which will be covered by pipe clips should be blasted and coated prior to fitting.

4.7.8 Pipeline exteriors should be blasted and coated at the same time as the lowermost parts of the tank. Any over-blast or over-spray affecting surrounding areas should be repaired.

4.7.9 Lighting during blasting and painting must be electrically safe and provide suitable illumination for all work.

4.7.10 Powerful spotlighting must be provided for inspection work.

4.7.11 Adequate ventilation during application and drying of all paints is essential.

4.7.12 Flexible ventilation trunking should be used to allow the point of extraction to be reasonably close to the applicator.

4.7.13 The ventilation system and trunking should be so arranged that 'dead spaces' do not exist. Ventilation must be maintained during application and continued whilst solvent is released from the paint film during drying.

4.7.14 The ventilation system must prevent the vapour concentration exceeding ten per cent of the lower explosive limit (or less than this if required by Regulations).

4.7.15 For coatings containing organic solvents, during the drying period an adequate number of air changes must be affected, depending on the type of coating being used. This ventilation should be maintained for at least 48 hours after the application of the system.

4.8 Surface preparation

4.8.1 Good surface preparation is one of the most important factors governing the performance of a coating. If contaminants such as oil, grease, dirt and chemicals are not removed from the surface they will prevent the adhesion of the coatings. Soluble salts on the surface may lead to osmotic blistering in the coating. Rust left on the surface will loosen, resulting in a loss of adhesion, and if mill scale is not completely removed it will cause accelerated corrosion.

4.8.2 Good surface preparation roughens the surface and enables a good mechanical bond to be achieved.

4.8.3 All oil and grease are to be removed from the surface with suitable solvents prior to blast cleaning.

4.8.4 All welded areas and attachments are to be given special attention for the removal of welding flux and weld spatter. Sharp edges should be smoothed and any surface irregularities, including rough weld caps and slag together with rough edges, fins and burrs, should be mechanically treated using power wire brushing, grinding or chipping as appropriate.

4.8.5 Only dry abrasive blast cleaning techniques are to be employed and the conditions under which blast cleaning is carried out should preclude condensation. In this respect blasting should not normally be carried out under any of the following conditions:

(a) The surface temperature of the steel is less than 3°C above the dew point;

(b) The relative humidity is above 85 per cent;

(c) When there is any possibility that the surface of the steel is wetted before the first coat is applied.

4.8.6 The compressed air supply used for blasting is to be free of water and oil and adequate separators and traps are to be provided. Prior to using compressed air, the quality of the air downstream of the separator should be tested by blowing the air onto a clean white blotter or cloth for two minutes to check for any contamination, oil or moisture, as described in ASTM D4285. This test should be performed at the beginning and end of each shift and at intervals of not more than four hours. If two consecutive tests show no contamination the interval can be extended to once per shift; if subsequent tests show contamination, then the four-hour interval is to be reinstated. The test also should be made after any interruption of the air compressor operation. The air should be used only if the test indicates no visible contamination, oil or moisture. If contaminants are evident, the equipment deficiencies should be corrected and the air stream should be re-tested.

4.8.7 Accumulations of oil and moisture are to be removed by regular purging of the system. Air compressors should not be allowed to work at temperatures in excess of 115°C.

4.8.8 The abrasive used for blasting should be dry, free from dirt, oil or grease, and suitable for producing the standard of cleanliness and profile specified. Additionally, any organic or water-soluble matter should be a maximum of 0,05 per cent by weight.

4.8.9 Iron or steel abrasives are not normally recommended for in situ open blasting. If used, careful and thorough cleaning must be carried out to remove all traces of abrasive from the surface.

4.8.10 Although not recommended, recycled grit may be used providing it is correctly graded, dry and free from dirt, oil, grease, and organic or water soluble matter. Recirculated grit should be checked for the presence of oil by immersing a sample in water and examining for oil flotation. Tests should be made at the start of blasting, and then every four hours until the end of blasting. If compressor operations are interrupted for longer than five minutes, the air supply should be re-tested prior to use. If oil is evident, the contaminated abrasive should be cleaned or replaced. All surfaces blasted since the last successful test should be completely re-blasted.

4.8.11 The amplitude of the blast profile from trough to adjacent peak depends upon the type of coating to be applied. The amplitude should be not more than 50 µm for coatings of the zinc silicate type and not more than 75 µm for high build coatings, unless otherwise specified by the manufacturer. A procedure to measure the surface profile of abrasive blast cleaned steel on site is given in NACE SP0287-2016-SG. The technique utilises a tape that replicates the surface profile, and the thickness of the tape is then measured using a micrometre.

4.8.12 Generally, where the final dry film coating is 125 µm or less, it should be in accordance with ISO 8501-1 Sa3 or an equivalent standard, i.e. the surface is to be cleaned to white metal such that a uniformly metallic, slightly roughened surface is produced completely free from foreign matter. Shadowed areas may only be accepted if they are due to differences in the structure of the steel or to a blast cleaning pattern. It should be noted that the possibility of achieving a uniform standard of Sa3 throughout the tanks is remote and a more realistic achievement would be somewhere between Sa2½ and Sa3.

4.8.13 The standard of surface preparation for the majority of the coatings is to be at least in accordance with ISO 8501-1 Sa2½ or an equivalent standard, i.e. the blast cleaned surface is to consist of at least 95 per cent cleaned bare steel and not more than ten per cent of any single 25 mm^2 of the surface area is to be discoloured by areas of rust stain or mill scale residues.

4.8.14 In cases where the substrate is corroded or pitted it may be necessary to fresh-water wash the areas after abrasive blasting, then re-blast, in order to ensure complete removal of soluble corrosion products.

4.8.15 No acid washes or cleaning solutions are to be used on metal surfaces after they have been blasted. This includes inhibitive washes intended to prevent rusting.

4.8.16 Any substandard areas should be identified and must be brought up to the specified standard. Grease-free chalk should be used to identify substandard areas and it should be removed after the substandard areas have been rectified.

4.8.17 After blast cleaning, all surfaces are to be freed of abrasive and dust by:

(a) Blowing with dry compressed air; or

(b) Vacuum cleaning. To confirm that the blasted surfaces are sufficiently dust-free to allow successful coating, they are to be tested in accordance with ISO 8502-3 or an equivalent standard, to an extent and with acceptance criteria defined by the coating manufacturer.

4.8.18 Where surfaces have been coated with a prefabrication primer they are to be similarly cleaned before application of the coatings. If there is extensive breakdown of the primer, the surface affected is to be re-blasted.

4.8.19 Since fresh blast cleaned surfaces are subject to immediate corrosion, particularly in areas of high humidity or in a marine atmosphere, it is essential that all cleaned surfaces are coated within four hours of cleaning. In any case, the surfaces are to be coated prior to the end of the working day and before any visible rusting occurs, unless humidity can be maintained overnight at a low level.

4.8.20 Checks on the steel surface cleanliness and roughness profile should be carried out at the end of the surface preparation and before the application of the primer, in accordance with the manufacturer's specifications.

4.8.21 Where abrasive blast cleaning is demonstrated to be impracticable at specific locations, alternative mechanical surface cleaning techniques may be applied. In such circumstances, the surface cleanliness should be in accordance with ISO 8501-1 St3 or an equivalent standard and particular attention must be given to ensuring that the surface profile and soluble salt concentrations are in accordance with the coating manufacturer's specification.

4.9 Coating requirements

4.9.1 The composition of any primer used to coat steel after surface preparation and prior to fabrication must be such that it will have no significant deleterious effect on subsequent welding work.

4.9.2 The coatings are to be compatible with any prefabrication primer used and suitable for the intended application.

4.9.3 Materials are to be delivered in original containers with labels intact and the seals unbroken. Containers are to be kept in a safe, clean, well-ventilated storage space.

4.9.4 Before use, coatings are to remain unopened in the original containers. Covers are to be kept on opened coating containers when not in use. Coatings are to be used in strict date order and not stored for longer than six months unless permitted by the paint manufacturer.

4.9.5 The coating manufacturer's instructions for storage, mixing, thinning and application of coatings are to be followed, along with the recommended time limit between coats and the health and safety precautions. Only the thinners recommended by the manufacturer are to be used to thin coatings.

4.9.6 Coatings are to be mixed immediately prior to application. All coating materials are to be thoroughly mixed to give a homogeneous liquid without pigment settling out during application. Mechanical mixers are to be used for all coating mixing operations. The entire contents of the coating container are to be used in mixing to ensure the correct proportion of the base coat and pigment.

4.9.7 Coating material which has livered, discoloured, gelled or otherwise deteriorated during storage is not to be used. Thixotropic materials which may be stirred to obtain normal consistency may be acceptable.

4.9.8 For coating materials requiring the addition of a catalyst, the pot life under application conditions is to be clearly stated on the label, and this pot life is not to be exceeded. When the pot life limit is reached, the spray pot is to be emptied, the material discarded, and new material mixed.

4.9.9 Specification and datasheets on the coating materials are to be available at all times.

4.10 Coating application

4.10.1 The application of a coating should be a well-planned activity, integrated into the yard's construction plans and carried out under controlled conditions to avoid conflicts with other yard operations.

4.10.2 Coatings should be applied in controlled humidity and surface temperature conditions to surfaces which have been blast cleaned to the coating manufacturer's recommended standard and immediately coated with a compatible prefabrication primer, or applied after blast cleaning if this is permitted by the specification.

4.10.3 Areas where the prefabrication primer is damaged in any way may be touched up in accordance with the manufacturer's specifications.

4.10.4 Each coating layer should have the maximum/minimum thicknesses in accordance with the coating specification. Generally, an 80/20 practice may be adopted, which means that 80 per cent of all thickness measurements should be greater than or equal to the nominal dry film thickness (DFT), and none of the remaining 20 per cent are below 80 per cent of the DFT. In

the case of tanks (and especially ballast tanks), consideration should be given to adopting a 90/10 practice, which means that 90 per cent of all thickness measurements should be greater than or equal to the nominal DFT, and none of the remaining 10 per cent are below 90 per cent of the DFT.

4.10.5 All paints should be applied by airless spray except for stripe coats, where brushes or, if recommended by the coating manufacturer as a preferred option, rollers may be used.

4.10.6 Conventional spray may be used for the spraying of zinc silicate tank coatings.

4.10.7 Efficient mechanical stirrers for the correct mixing of paint should be used.

4.10.8 The spray equipment should comply with the paint manufacturer's recommendations. Adequate moisture traps should be fitted where appropriate so that water or oil can be continuously bled off from the air supply.

4.10.9 Lines and pots are to be thoroughly cleaned before using different materials.

4.10.10 With the possible exception of wet blast primers and moisture cured products, coatings should not be applied to damp surfaces and the specification should stipulate that coatings are not to be applied to surfaces where the relative humidity of the atmosphere is such that:

(a) Condensation is present on the surface; or
(b) It will affect the application or drying of the coating.

4.10.11 No coating is to be applied if the temperature is below that specified by the coating manufacturer and, in general, the metal surface temperature should be at least 3°C above the dew point before painting is commenced. The temperature, dew point and relative humidity should be determined with a sling psychrometer. Suitable procedures are given in ASTM E337. Readings are required at the start of work and every four hours afterwards.

4.11 Coating thickness

4.11.1 Generally, high duty coatings should be applied in at least two coats; however, 'wet-on-wet' application may be considered as a two-coat system provided:

(a) There is a time interval between the coats; and
(b) There is adequate attention to difficult areas such as welds, edges and any other changes in section, and that the recommended coating thickness is achieved over all the structure.

4.11.2 Where coatings other than the zinc silicate type have been accepted as a single coat application, all welds, edges and any other changes in section may require a stripe coat to be applied.

4.11.3 Successive coats should preferably be of different colours or with a significant shade variation to give contrast and ensure complete coverage of the surface, *see also Ch 6, 4.5 Surface preparation and the application and maintenance of coatings 4.5.10*.

4.11.4 All surfaces are to receive the full thickness specified as a minimum. Areas with inadequate coating thickness should receive additional compatible coats until the specified coating thickness is attained. Coatings are to be brushed onto all areas which cannot be properly coated by spray.

4.11.5 Care should be taken to avoid an excessive coating thickness as this could lead to serious consequences, such as solvent and thinner retention, film cracks, gas pockets, etc. Wet coating thickness should be checked during application.

4.11.6 Each coating layer should be adequately cured before application of the next coat, in accordance with the coating manufacturer's recommendations. Intermediate coats must not be contaminated with dirt, grease, dust, salt, over-spray, etc. Job specifications should include the dry-to-recoat times given by the manufacturer.

4.11.7 Thinners should be limited to those types and quantities recommended by the manufacturer.

4.12 Inspection and repair

4.12.1 Wet film thickness checks should be made as the work progresses using appropriate thickness gauges.

4.12.2 Dry film thickness determinations should be carried out on all significant areas using suitable gauges (the simple pull-off type gauges are not considered sufficiently accurate for this work).

4.12.3 The full number of coats specified should be applied and the specified film thickness achieved.

4.12.4 All coatings should be free of pin holes, voids, bubbles and other 'holidays'. Holiday testing should be carried out using a suitable 'holiday detector' set at an appropriate voltage for the coating system.

4.12.5 Any defective areas are to be marked up and appropriate repairs effected. All such repairs are to be rechecked for any uncoated areas.

4.12.6 A daily log of the following is to be prepared:

(a) Air and steel temperatures;
(b) Relative humidity;
(c) Paint thicknesses measured;
(d) Extent of coating;
(e) Any other relevant information.

4.12.7 Damage to coatings is to be repaired by cleaning back to a sound base, recoating the affected areas as required in the specification and feathering to tie with adjoining areas. Prior to the application of any coating, all damage to previous coats is to have been repaired.

4.12.8 The area to be cleaned is to be carried over onto the firm surrounding coating for not less than 25 mm all-round the edges. These are to be feathered by a suitable method to ensure continuity of the subsequent repair coating.

4.12.9 Areas with inadequate coating thickness are to be thoroughly cleaned and, if necessary, abraded and, where applicable, additional coats applied until the specification is complied with. These additional coats are to blend in with the final coating at adjoining areas.

4.12.10 Where welding has to take place on coated areas, unless they are approved prefabrication primers the coatings are to be removed locally and the surface after welding is to be prepared and recoated in accordance with the recommended procedures.

4.12.11 When dry film thicknesses are less than those specified, additional coats are to be applied as necessary to achieve the specified thickness. For inorganic zinc silicate, areas of low film thickness should not be repaired by additional coats. In this case the coating is to be removed and the area recoated to the specified thickness or paint manufacturer's recommendation.

4.13 Safety aspects

4.13.1 It should be noted that paints, coatings and thinners are potentially hazardous from health and safety points of view if not strictly controlled in accordance with good practice. Detailed advice on the safe working practices to be followed should be obtained from the relevant governmental safety agencies.

4.14 Maintenance

4.14.1 Maintenance of the corrosion protection system should be included in the overall maintenance schemes.

4.14.2 The most efficient way to preserve the corrosion protection system is to repair any defects found during the in-service inspections (e.g. spot rusting, local breakdown at edges of stiffeners, etc.).

4.14.3 During maintenance hard coatings should be restored by using the type originally applied or a compatible hard coating recognised by LR. The compatibility of coatings should normally be agreed by the paint manufacturer, and the coatings should be applied in accordance with the manufacturer’s requirements.

4.14.4 The restoration of the damaged hard coatings by using compatible coatings not recognised by LR will be accepted, provided such coatings are applied and maintained in accordance with the manufacturer’s specification. Details of such coatings are to be reported for information and record purposes.

4.14.5 If the required conditions for the application of the original coating are not achievable, a coating more tolerant of a lower quality of surface treatment, humidity and temperature conditions may be considered, provided that it is applied and maintained in accordance with the manufacturer’s specifications.

4.14.6 Currently there are numerous non-oxidising soft coatings which are being marketed for the purpose of repairing hard coatings. Proposals to use these coatings, including the manufacturer’s confirmation of their compatibility with the existing coatings, are to be referred for consideration.

4.14.7 It should be noted that soft coatings are, in general, not suitable for use in association with cathodic protection.

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Section 1
General principles

1.1 General

1.1.1 Design and construction of fixed offshore attended and unattended oil and gas production platforms shall meet the safety requirements of recognised International Standards such as API RP 14J, ISO 10418 and their referenced Standards.

1.1.2 Design, installation and operation of the platform safety systems (including emergency shutdown, isolation, and depressurisation systems) shall meet the requirements of recognised International Standards such as API RP 14C and ISO 13702.

1.1.3 This document can be applied both to normally attended installations and to normally unattended installations, provided the occupancy risks are considered in the risk analysis referred to in *Ch 7, 2 Production systems*.

Section 2
Production systems

2.1 General

2.1.1 The provisions described in this Section are applicable to facilities on fixed installations of various configurations that provide hydrocarbon production and processing services. These services may include (but are not limited to): well fluid depressurisation, reinjection, phase separation, transfer, fluid cleaning, treatment and stabilisation, storage, dehydration, metering, compression, and offloading of processed hydrocarbon.

2.1.2 All production systems shall be subject to hazard and risk assessment in accordance with ISO 17776 or equivalent. Identified risks should then be subject to measures to prevent or mitigate the hazard as appropriate. Protective measures, such as automated safety systems and mechanical safety systems, or mitigation systems, such as fire and gas systems, shall be designed to meet the requirements of recognised International Standards as applicable to the system itself.

2.1.3 Guidance applicable to systems, sub-systems, equipment and/or components for handling and processing produced hydrocarbons from completed wells is given in *Pt 3, Ch 3 Production and Storage Units* and in *Pt 3, Ch 8 Process Plant Facility* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* . These provisions address process equipment such as process vessels, heat exchangers, fired heaters, compressors and pumps, as well as the associated piping, process control, and process safety systems.

2.2 Recognised industry standards

2.2.1 The facility design is to be in accordance with the requirements of this RP and the specified codes and/or standards as referenced herein, and of *Pt 12 Recognised Codes and Standards for the Classification of Offshore Units* of the *Rules and*

Regulations for the Classification of Offshore Units, July 2022 or an agreed set or recognised International Codes and Standards as applicable to this type of facility.

2.2.2 Designs complying with other International or National Standards not referenced in *Ch 7, 2.2 Recognised industry standards 2.2.1* will be subjected to consideration.

2.2.3 When alternate design codes and/or standards are proposed, justifications should be provided to demonstrate that the proposed alternative design code and/or standard provides an equivalent level of safety to the recognised standards as listed in the referenced Rules.

2.3 Design conditions

2.3.1 The production and process plant is to be designed for all operating and foreseeable abnormal conditions in accordance with recognised and agreed codes or standards, and should take into account the following:

(a) Environmental conditions such as earthquake, temperature, ice, snow, wind and storm event as applicable to the location of the facility.
(b) Operational loads such as static pressure, transient pressures such as surge or blast, temperature excursion, vibration and static head.
(c) Transportation.
(d) Installation.
(e) Commissioning.
(f) Test loads.

2.4 Submissions of design plans and data

2.4.1 The submitted design plans and data are to be in accordance with the requirements of this RP and the latest edition of the specified codes and/or standards, as referenced above. It should be noted that because of the varying configurations of offshore production facilities, portions of these requirements may not be applicable to a given installation.

2.4.2 The technical documentation required from the production facilities and submitted for review is typically:

(a) Basis of design;
(b) Project philosophies such as emergency shutdown (ESD), relief and blowdown, isolation, hazardous areas, layout and piping, stress analysis, etc.;
(c) Equipment layouts or plot plans, piping arrangements;
(d) Piping and Instrument Diagrams (P&IDs), Process Flow Diagrams (PFDs);
(e) Risk studies or reports such as fire and explosion, HAZOP, HAZID, QRA, LOPA, SIL determination and SIL Validation cold spill, firewater demand, etc.;
(f) Process calculations or reports such as line sizing for overpressure protection devices, flare KO drums, surge on offloading systems, surge on hot oil and cooling water systems, etc.;
(g) Overpressure and underpressure protection devices calculations or reports and datasheets;
(h) Relief, blowdown and flare calculations or reports;
(i) Flare calculations inclusive of radiation, dispersion of combustion gases and flame out condition;
(j) Cold vent calculations inclusive of dispersion of vented gases and radiation due to unexpected ignition;
(k) Flow induced vibration (FIV) and acoustic induced vibration (AIV) assessment;
(l) Piping and valve materials specifications and datasheets;
(m) Equipment specification and datasheets;
(n) Line lists and critical line lists;
(o) Cause and effects matrix;
(p) Control schematics;
(q) Piping stress analysis;
(r) Classification of hazardous area schedule and drawings.

2.4.3 The technical documentation required for review for equipment, packages and components is typically:

(a) Model and size;
(b) Design specifications, including design codes, standards and references;
(c) Design parameters: loads, temperature, environmental conditions etc.;
(d) Design analysis and/or calculations, as applicable;

(e) Dimensional details and drawings;
(f) Fabrication details and welding configurations;
(g) Material specifications and material properties.

2.4.4 Equipment, packages and product certification levels and requirements may be determined in accordance with *Pt 3, Ch 19 Equipment Categories* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*, and/or guidelines provided by IOGP JIP 33 Standardizing procurement specifications, Conformity Assessment System (CAS) levels A to D, which reflect the intended level of purchaser's intervention for each of the four levels.

Section 3
Support systems

3.1 General

3.1.1 Support systems are utility and auxiliary systems that complement the hydrocarbon production and process systems.

3.1.2 In general, design of those systems is to comply with API RP 14J, or other recognised codes and/or standards.

3.1.3 Further guidance for utility systems and platform process support systems is given in *Pt 3, Ch 8 Process Plant Facility* and *Pt 5 Main and Auxiliary Machinery* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

3.2 Containment, spill and drainage

3.2.1 Drainage systems are to be provided to collect and direct drained or escaped liquids to a location where they can be safely handled or stored. In general, the production and process plant facility is to be provided at least with:

(a) A closed drainage system to collect produced liquids from equipment and piping;
(b) A hazardous open drainage system to collect leaks and spillage from designated hazardous areas;
(c) A non-hazardous open drainage system to collect leaks and spillage from designated non-hazardous areas; and
(d) A chemicals drainage system to collect leaks and spillage from areas in which chemicals will be handled or stored.

3.2.2 Drainage systems are to be entirely separate from each other and distinct in order to prevent a route for the migration of a fire, flammable liquids or vapours from one hazardous area to another, or to non-hazardous areas.

3.2.3 Design of the platform drain system should be in accordance with the provisions indicated in *Pt 3, Ch 8 Process Plant Facility* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to the type of facility.

3.3 Vent system

3.3.1 Design of the platform vents should follow the provisions indicated in *Pt 3, Ch 8 Process Plant Facility* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

Section 4
Pressure relief, vent and blowdown systems

4.1 General

4.1.1 All production systems are to include safety devices that are integrated into an automatic safety system designed to shut down, isolate and/or depressurise part or all of the production system upon the detection of process upsets or component failure.

4.1.2 Mechanical safety devices such a relief valves, etc. shall be designed in accordance with recognised industry standards such as API 520, etc.

4.1.3 Design and application of the vent, flare and depressurising system shall be in accordance with API STD 521. Additional guidelines are provided in *Pt 3, Ch 8, 3.5 Overpressure and underpressure protection* and *Pt 3, Ch 8, 3.9 Flare and radiation levels* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

4.2 Sequential blowdown

4.2.1 Where sequential blowdown systems are used to depressurise process units, individual components are to perform in a consistent and complimentary manner and so that no one single failure can impact on the performance of the blowdown sequence. The following will be required:

(a) The blowdown sequence is to ensure that the system is to be blown down in a suitable order in accordance with the detected hazard, to the required pressure, within the time allowed; and that it will not overload the flare system.

(b) The electrical power system is to be reviewed to ensure that the design is robust and that the loss of one single UPS, or cable, will not prevent the correct blowdown sequence from being carried out. This will require an understanding of the blowdown sequence.

(c) The Safety Instrumented System is designed to ensure that the software sequence controller, I/O cards, etc. cannot cause a single point failure.

■ *Section 5* Wellheads

5.1 General

5.1.1 Wellhead design shall comply with API spec 6A/API 17D requirements or other recognised codes and/or standards.

■ *Section 6* Electrical and instrumentation systems

6.1 Electrical

6.1.1 The electrical installation is to be designed, installed and tested in accordance with all parts of IEC 61892 or other relevant National Standards for electrical installations, amended where necessary for ambient temperature and other environmental conditions.

6.1.2 Attention is also to be given to any relevant statutory regulation of the National Administration in the country in which the unit is to operate and/or be registered.

6.2 Design documentation

6.2.1 Electrical system study and calculations are to be in accordance with the IEC 61892-2 or an alternative relevant International or National Standard.

6.2.2 The general arrangement of the unit, showing the hazardous zones and spaces, is to include details on the permitted temperature class and gas group of the electrical equipment. The temperature class and apparatus group of the electrical equipment are associated with the ignition temperature and energy required for ignition of the hazardous substances.

6.3 Design and construction of equipment

6.3.1 Equipment or apparatus required to be suitable for use in an explosive gas atmosphere shall comply with the requirements of:

- *Pt 6, Ch 2, 8 Protection from electric arc hazards within electrical equipment*;
- *Pt 6, Ch 2, 9 Rotating machines*;
- *Pt 6, Ch 2, 10 Converter equipment*;
- *Pt 6, Ch 2, 11 Electrical cables and busbar trunking systems (busways)*;
- *Pt 7, Ch 2 Hazardous Areas and Ventilation* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*;
- codes;
- IEC 60092-502;
- IEC 61892-7, or alternative relevant International or National Standard.

Such equipment shall be constructed and tested in accordance with the requirements of the IEC 60079 series (or alternative relevant International or National Standard), and be suitably certified for the actual ambient temperature and other environmental conditions.

6.4 Location and construction of equipment

6.4.1 The requirements for location and construction are given in IEC 61892-1, amended where necessary for ambient temperature and other environmental conditions.

6.4.2 Electrical equipment, as far as is practicable, is to be located:

- Such that it is accessible for the purpose of maintenance and survey;
- Clear of flammable material;
- In spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions;
- Where flammable gases cannot accumulate;
- Where it is not exposed to the risk of mechanical injury or damage from water, steam or oil, and, clear of areas at risk of cryogenic spills.

6.4.3 Equipment located in hazardous areas, or required to remain operational during catastrophic conditions, is to comply with the relevant requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

6.4.4 Where electrical equipment is located within areas or adjacent to areas protected by a fixed water-based location application fire-fighting system, it is to be protected in the event of system operation.

6.5 Earthing of non-current-carrying parts

6.5.1 The requirements for earthing of non-current-carrying parts are given in IEC 61892-6.

6.6 Bonding for the control of static electricity

6.6.1 The requirements for bonding for the control of static electricity are given in IEC 61892-6.

6.6.2 Bonding straps for the control of static electricity are required for storage tanks, process plant and piping systems located in hazardous areas, or for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the structure of the unit either directly or via their bolted or welded supports and where the resistance between them and the structure exceeds 1 MΩ.

6.7 Lightning protection

6.7.1 The provisions for lightning protection are given in IEC 61892-6.

6.8 Main source of electrical power

6.8.1 The requirements for the main source of electrical power are given in IEC 61892-2.

6.9 Emergency source of electrical power

6.9.1 The requirements for the emergency source of electrical power are given in IEC 61892-2.

6.9.2 Provision is to be made for periodic testing of the emergency power system to demonstrate that emergency services can be supplied automatically following the loss of the main source of electrical power.

6.9.3 Where the guidance specifies that a service is required to be connected to both the main and the emergency source of electrical power or is to be connected to the emergency switchboard, these services are to be served by at least two individual circuits from the separated main sources of electrical power with arrangements to transfer between the two sources. The supplies are to be separated in their switchboard and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single electrical fault will not cause the loss of both supplies.

6.10 Supply and distribution

6.10.1 While both insulated and earthed distribution systems (TN-S) are permitted, systems which may result in the presence of electrical currents within the hull or unit structure return (TN-C and TN-C-S) are not permitted, with the exception of:

(a) Limited and locally earthed systems outside any hazardous area;

(b) Intrinsically safe systems;

(c) Impressed current cathodic protection systems.

6.10.2 Systems installed in hazardous areas shall comply with the requirements of:

- *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*;
- *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*;
- *Pt 7, Ch 2, 10 Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk*; and
- *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*

6.11 Isolation and switching

6.11.1 Isolation and switching are to be by means of a circuit-breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) Switching off the circuit on load;

(b) Withstanding, without damage, the overcurrents which may arise during overloads and short-circuit.

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches.

6.11.2 Devices selected for isolation of circuits shall comply with the relevant International or National Standards.

6.12 Insulated distribution systems (IT systems)

6.12.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to monitor continuously the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance and/or high level of leakage current.

6.13 Earthed distribution systems (TN systems)

6.13.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

6.13.2 A device(s) is to be installed for every earthed distribution system, whether primary or secondary, for power, heating and lighting circuits, to monitor continuously the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance and/or high level of leakage current. This does not apply to the following systems:

(a) Limited and locally earthed systems outside any hazardous area;

(b) Intrinsically safe systems;

(c) Impressed current cathodic protection systems.

6.14 High voltage distribution systems

6.14.1 For systems with a nominal voltage of 15 kV a.c. or greater, the neutral (star point) shall be earthed by one of the following methods:

(a) High impedance resistor;

(b) Earthing transformer.

6.14.2 The earth fault current should be as low as is reasonably practicable to allow the earth fault protection to operate in a time specified by the protection coordination study and to minimise touch voltages. Systems with resonant earthing (Petersen coil) are not permitted.

6.14.3 Earthing systems serving high voltage systems, including systems with a nominal voltage of 15 kV a.c. or greater, shall be solidly interconnected with the LV system earthing network to minimise touch voltages. The touch voltages and fault durations shall not exceed the values given in Annex B Touch Voltage and Body Current of BS EN 50522.

6.15 System design - Protection

6.15.1 The general requirements for protection are given in IEC 61892-2.

6.16 Protection against earth faults

6.16.1 Where any circuit, other than an intrinsically safe circuit, passes into or through any Zone 0 area, the circuit is to be disconnected automatically and/or is to be prevented from being energised in the event of an abnormally low level of insulation resistance and/or high level of leakage current.

6.16.2 Where a circuit passes into any Zone 0 area, the protective systems shall be arranged so that manual intervention is necessary for the reconnection of the circuit after disconnection as a result of a short-circuit, overload or earth-fault condition.

6.17 Is Limiters

6.17.1 The use of Is Limiters is permitted in situations where circuit-breakers cannot provide any protection against unduly high peak short-circuit currents, as circuit-breakers are too slow. The Is Limiter is capable of detecting and limiting a short-circuit current only during the first rise, i.e. in less than 1 ms with the maximum instantaneous current occurring remaining below the level of the peak short-circuit current of the system.

6.18 Protection of generators

6.18.1 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse in each insulated pole will be acceptable.

6.19 Harmonic filters

6.19.1 Harmonic filters' final sub-circuits are to be protected individually and individually on each phase against overload and short-circuit. The activation of the protection arrangement in a single phase shall result in automatic disconnection of the complete filter.

6.19.2 A current imbalance detection system is to be installed; it is to be independent from the protection specified in paragraph *Ch 7, 6.5 Earthing of non-current-carrying parts 6.5.1*.

6.19.3 An alarm is to be initiated in the event of protective device operation or current imbalance that could lead to failure of harmonic filter.

6.19.4 Current imbalance circuits are to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated components but also of the complete installation.

6.19.5 The reconnection of harmonic filters is to require manual intervention.

6.19.6 Individual harmonic filter capacitors are to be provided with a pressure relief valve or overpressure disconnector to protect against damage from rupture where pressure build-up within hermetically sealed capacitors may occur.

6.20 Switchgear and control gear assemblies

6.20.1 The general requirements for switchgear and control gear assemblies and their components are given in IEC 61892-3.

6.21 Busbars

6.21.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidisation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

6.21.2 For bare conductors, where no precautions are taken against surface oxidisation, the temperature rise limit at rated normal current is not to exceed 45°C. Where suitable precautions are taken against surface oxidisation, e.g. by using silver, nickel or tin coated terminations, a temperature rise limit not exceeding 60°C is permitted. Where the busbar temperature rises are above 45°C it is to be ensured that there is no adverse effect on equipment adjacent to and/or connected to the busbars and that the temperature rise limits of any materials in contact with the busbars are not exceeded. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

6.22 Wiring

6.22.1 Insulated wiring connecting components is to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

6.23 Position of switchboards

6.23.1 So far as possible, pipes should not be installed directly above, in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions.

6.23.2 For switchgear and control gear assemblies, for rated voltages above 1 kV a.c., arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200 or Annex B of IEC 62271-203.

6.24 Switchboard auxiliary power supplies

6.24.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

6.25 Rotating machines

6.25.1 The requirements for the construction, performance, control and testing of rotating machines are given in IEC 61892-3.

6.26 Transformers

6.26.1 The requirements for transformers are given in IEC 61892-3.

6.26.2 Transformers are to comply with the requirements of IEC Publications 60076, *Power transformers*, or alternative relevant International or National Standards amended where necessary for ambient temperature and other environmental conditions.

6.27 Semi-conductor converters

6.27.1 The requirements for semi-conductor converters are given in IEC 61892-3.

6.27.2 Semi-conductor converters are to comply with the requirements of IEC 60146.

6.28 Uninterruptible power systems (UPS)

6.28.1 The requirements for uninterruptible power systems are given in IEC 61892-3.

6.28.2 UPS units are to comply with the requirements of IEC 62040.

6.28.3 An external bypass, which is hardwired and manually operated, is to be provided to the UPS, to allow for isolation of the UPS for safety during maintenance and to maintain continuity of load power. When the UPS is operating in either normal or bypass mode it must be ensured that there are no multiple system earths.

6.29 Electrical cables, optical fibre cables and busbar trunking systems (busways)

6.29.1 The general requirements for electrical cables are given in IEC 61892-4.

6.29.2 Optical fibre cables for fixed installations are to comply with a relevant International or National Standard amended where necessary for ambient temperature and other environmental conditions, which is to address the following properties:

(a) Flame retardancy;
(b) Fire resistance (if applicable);
(c) Smoke density;
(d) Halogen content;
(e) Mechanical properties;
(f) Suitability for use in the offshore environment.

6.29.3 Subsea and umbilical cables are to comply with a relevant International or National Standard amended where necessary for ambient temperature and other environmental conditions, which is to address the following properties:

(a) Current and voltage ratings;
(b) Operating depths;
(c) Ambient temperature limitations;
(d) Corrosion protection;
(e) Suitability for use in the offshore environment.

6.29.4 Electrical cables for telecommunications and data transfer are to be selected in accordance with the recommendations of IEC TR 60092-370.

6.29.5 Busbar trunking systems (busways) are to comply with a relevant International or National Standard that is to address the following properties:

(a) Minimum enclosure rating of IP54 to IEC 60529;
(b) Fire and watertight integrity;

(c) Partial flooding;
(d) Robustness and corrosion resistance of supports;
(e) Security to the unit structure.

6.30 Batteries and hybrid power systems

6.30.1 The requirements for batteries of the vented and valve regulated sealed type are given in IEC 61892-3. *See Pt 6, Ch 2, 12 Batteries* of the *Rules and Regulations for the Classification of Ships, July 2022* for guidance in respect of lithium battery installations.

6.30.2 For guidance on hybrid electrical power systems, *see Pt 6, Ch 2, 24 Hybrid electrical power systems* of the *Rules and Regulations for the Classification of Ships, July 2022*.

6.31 Equipment – Heating, lighting and accessories, electric trace heating and underwater systems

6.31.1 The requirements for heating and cooking equipment, lighting, socket outlets and plugs, and equipment enclosures are given in IEC 61892-3.

6.32 Electric trace heating

6.32.1 Electric trace heating shall comply with IEC 61892- 3. Trace heating installations in hazardous areas shall comply with IEC 60079-30 or a relevant International or National Standard amended where necessary for ambient temperature and other environmental conditions.

6.33 Refrigeration

6.33.1 Refrigeration required in units to facilitate LNG production and/or cryogenic storage is to comply with the requirements of IEC 60092-502. Control and instrumentation associated with refrigeration systems is to comply with IEC 60092-504.

6.34 Lighting, navigation and emergency alarm and communication systems

6.34.1 The requirements for lighting circuits are given in IEC 61892-2, amended where necessary for ambient temperature and other environmental conditions.

6.34.2 Escape lighting fittings supplied by a central battery system or UPS are to be connected to the power source using fire resistant cables and comply with the relevant International or National Standards amended where necessary for ambient temperature and other environmental conditions.

6.34.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit.

6.34.4 Where lighting circuits in a stored oil pump-room adjacent to a storage tank are also used for emergency lighting, and have been interlocked with ventilation, the interlocking arrangements are:

(a) Not to cause the lighting to go out following a failure of the ventilation system; and
(b) Not to prevent operation of then emergency lighting following the loss of the main source of electrical power.

6.35 Navigational aids

6.35.1 Navigational aids (lanterns and sound signals) shall be provided in accordance with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) requirements and the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

6.35.2 Navigational aids are to be fed from the emergency source of electrical power and from the main source of electrical power.

6.36 Helideck and aircraft warning lights

6.36.1 Helideck perimeter lighting, helideck floodlights, aircraft warning lights, status (wave-off) lights and unit identification signage are to comply with CAP 437 or the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

6.36.2 Helideck perimeter lighting, helideck floodlights, aircraft warning lights and status lights are to be supplied by a UPS backed supply. The UPS autonomy is to be in accordance with the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

6.37 Emergency alarm and communication systems

6.37.1 The acoustic and optical signals and indications used in alarm systems shall meet the requirements of the IMO Code on Alerts and Indicators.

6.37.2 Communication and alarm systems intended to be used in an emergency are to be functional under fire conditions.

6.37.3 The systems are to be fed from the emergency source of electrical power and from the main source of electrical power.

6.38 Testing and trials

6.38.1 All electrical equipment is to be tested complete or in sections at the manufacturer's premises and a test report issued by the manufacturer. The test procedures are to be in accordance with *Pt 6, Ch 2, 21.1 Testing* of the *Rules and Regulations for the Classification of Ships, July 2022* or an equivalent International or National Standard.

6.38.2 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials of IEC 61892-6. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

6.38.3 Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test and insulation resistance test is to be satisfactorily carried out on each completed cable and its accessories. The test procedures are to be in accordance with *Pt 6, Ch 2, 21.3 High voltage cables* of the *Rules and Regulations for the Classification of Ships, July 2022*.

6.38.4 Where on-line partial discharge monitoring equipment is installed for the monitoring of high voltage rotating machines, the equipment is to be tested in accordance with the procedures of *Pt 6, Ch 2, 21.4 On-line partial discharge testing of high voltage rotating machines for essential services* of the *Rules and Regulations for the Classification of Ships, July 2022*.

6.38.5 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules or the codes and standards used in the design of the installation. The equipment is also to be examined to ensure that the equipment has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired. The guidance given in IEC 60079 Part 17 is acceptable for use for these inspections.

6.38.6 Alarms and interlocks associated with pressurised equipment and the ventilation of spaces located in hazardous areas are to be tested for correct operation.

6.38.7 Where Optical Fibre Communications systems are installed, they are to be tested in accordance with the procedures of *Pt 6, Ch 2, 21.6 Optical Fibre Communications Systems* of the *Rules and Regulations for the Classification of Ships, July 2022*.

6.39 Instrumentation

6.39.1 Field instrumentation

6.39.2 Instrumentation required as part of the control or ESD systems, should be specified, designed and installed in accordance with recognised industry standards for each type of instrument. Typical requirements for instrumentation are addressed in standards such as BS 6739.

6.39.3 Local instruments for operational reasons should be provided and installed as per approved P&IDs. Where instruments are used for calibration of transmitters, etc. the operating range should exceed the minimum and maximum values of the instrument to be calibrated.

6.39.4 All instrumentation shall be suitable for use in a marine environment, with ingress protection in accordance with IEC 60529 and rated for the environment in which it is intended to operate. If located in a hazardous area equipment shall be certified in accordance with standards such as IEC 60079 for the relevant gas group and temperature class. Consideration should be given to the operating environment for which the instrumentation is installed, with respect to operating temperatures and housing, heated if necessary, used to protect against extremes of temperature variations or in some cases Sunshades should be used to protect against solar radiation for the same reasons.

6.39.5 Instrumentation with process wetted parts shall have materials suitable for use with the process fluids for which they are installed.

6.39.6 Instruments certified by LR under the Type Approval process may provide assurance of their suitability of use. However, it should be considered that many of the above requirements are process specific and credit can only be taken for certification that is within the project conditions, e.g. temperature ranges.

6.40 Instrument installations

6.40.1 The requirements of this sub-Section apply to installations downstream of piping isolation valves.

6.40.2 Installations should be designed and constructed in accordance with the manufacturer's recommendations. For instruments connected to process fluids, the positions of tapping points relevant to the instrument can impact on the accuracy and performance of the instrument and should be considered during installation. Where temperature considerations require the process fluids to be kept at specific temperatures, heat tracing should be used.

6.40.3 Due consideration should be given to access for maintenance, risk of damage due to dropped objects, vibration, etc.

6.40.4 Typical requirements for instrumentation installations are addressed in standards such as BS 6739 and IEC 60092-504 part 504.

6.40.5 Where safety systems require multiple instruments to provide integrity or reliability, such as two out of three voting systems, consideration should be given to minimising common cause failures. Examples are as shown below:

- Separation of process connections;
- Separation of local cable routes and junction boxes;
- Diversity of cable and cable routes;
- Avoidance of common cause failure on input cards in the Safety Instrumented System (SIS).

6.41 Control systems

6.41.1 Control systems (also known as Basic Process Control Systems (BPCS)) are designed to control the process. Unless the BPCS is required to carry out a safety function it is not normally considered as part of the safety and protection systems and therefore is outside the scope of LR review. An exception to this, is when the demand on the SIS is caused by a failure of the BPCS. Under these circumstances the BPCS needs to be designed to meet the assumed failure rates of the BPCS when considered as part of the Safety Classification or SIL review.

6.41.2 Alarms are provided for operational reasons and in some cases used as a layer of protection. For this reason, some alarms will be required to be designed in accordance with recognised industry standards such as EEMUA. Consideration should be given to:

- Human-computer interfaces;
- Alarm management;
- Alarms set points with respect to Operator time to respond.

6.42 Safety Instrumented Systems (SIS)

6.42.1 Emergency shutdown systems (ESD), also known as SIS, are designed to protect the process systems against process upsets and to place the facility into a safe state. SIS design, build, construction and testing should comply with IEC 61508/61511 or equivalent standards recognised by LR.

6.42.2 A manual shutdown system shall serve as backup to the automatic system. The safety systems shall be tested and inspected on a regular basis to provide confidence that they will function as designed. Systems with multiple level shutdowns, to include blowdown and/or platform abandonment, should be documented on an ESD hierarchy diagram. Where maintenance overrides are used, they should be clearly identified and either key operated under a permit system or periodically alarmed on the BPCS operation stations until the override has been removed.

6.42.3 SIS may be designed using conventional relay logic, solid state devices or programmable controllers. Where programming is required to perform the logic, programming languages and requirements should meet the requirements of the relevant sections of IEC 61511-1. The use of independently certified function blocks will be acceptable, providing they are used within the parameters specified in the certification. Bespoke function block design will be required to be specifically designed, tested and verified to ensure that it meets the requirements of the design.

6.43 High Integrity Pressure Protection Systems (HIPPS)

6.43.1 Where Instrumented Pressure Protection Systems are used as an alternative to Pressure Relief devices, as permitted by standards such as ISO 10418, they should be designed and installed in accordance with IEC 61508/61511 or equivalent. If the demand scenario on the HIPPS is failure of any Safety Instrumented Function (SIF), the HIPPS system shall be independent of the SIS with respect to sensors, logic solvers and final elements.

6.44 Subsea controls located on topsides

6.44.1 Subsea controls units located on the topsides are outside the scope of this document. Interfaces between the topsides process facilities and subsea controls that can impact on the safety of the topsides facilities should be subject to review in accordance with other Safety Instrumented Systems.

Section 7
Networks and cyber security

7.1 Information Technology (IT) Systems

7.1.1 IT systems can be defined as carrying data used to support normal operations for the offshore installations. Typically, this would include systems such as voice communications, offshore/onshore data transfer systems etc. Whilst these systems are not considered safety critical, any interface points with OT systems are a potential security weak point. Network system architecture diagrams will be reviewed to ensure any data links are sufficiently protected against attacks, whether malicious or otherwise and from internal and external sources.

7.2 Operational Technology (OT) Systems

7.2.1 OT systems can be defined as data systems used to carry out the control, monitoring, alarm and shutdown of the topsides process facilities. They also include safety critical interfaces between the topsides and other systems such as subsea control. Consequently, OT systems are considered part of the safety systems for topsides facilities.

7.3 Cyber security requirements

7.3.1 Safety systems are required to be in accordance IEC 61511. A requirement of this standard is that security risk assessments are carried out. This requirement includes both physical and electronic security. Depending on the location of the installation, there may be specific national requirements which will be reviewed. As a minimum LR will review the risk assessment process required of IEC 61511 and should follow the route of recognised industry standards such as IEC 62443.

7.3.2 Cyber risks can be categorised as malicious or accidental, from internal or external threats, and due to physical or electronic actions. Regardless of the causes, the consequences can impact on safety or environmental issues. All these factors need to be considered when assessing risk. Risk assessments can be applied to both physical and electronic risks. Further operational guidance can be obtained by referring to documents such as UK HSE OG86.

Section 8
Piping systems and static pressure equipment

8.1 General

8.1.1 Process and utility piping systems design criteria are to be in accordance with API RP 14E, ASME B31.3 or other recognised International Codes and/or Standards such as ISO 13703, ISO 14692 and ISO 15649 applicable NFPA standards.

8.1.2 Accidental loads such as blast/explosion are to be considered and the acceptance criteria of relevant industry standards/International Standards or project specifications aligned to the latter shall be applied.

8.2 Pressure vessels, atmospheric tanks and heat exchangers

8.2.1 Design and application of the pressure systems are to comply with the requirements of suitable codes and/or standards selected as per *Ch 7, 2.2 Recognised industry standards*.

8.3 Boilers and fired heaters

8.3.1 Design and application of the fired equipment and systems are to comply with the requirements of suitable codes and/or standards selected as per Ch 7, 2.2 Recognised industry standards.

Section 9
Mechanical equipment

9.1 General

9.1.1 Machineries for hydrocarbon production and processing systems, sub-system components and equipment, and essential and emergency services should be in compliance with a relevant code or standard as referenced in *Pt 12 Recognised*

Codes and Standards for the Classification of Offshore Units of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

9.1.2 Designs complying with other International Standards or National Standards not listed on the *Pt 12 Recognised Codes and Standards for the Classification of Offshore Units* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* will be subject to consideration.

9.2 Pumps

9.2.1 Process and utilities pumps are to comply with a relevant International Standard such as API STD 610, API STD 674 or any other recognised International Codes and Standards applicable to the specific type of pump.

9.2.2 The fire pump system should be designed, installed, tested and maintained in accordance with NFPA 20 and NFPA 70 where possible.

9.3 Compressors

9.3.1 Process and utilities compressors are to comply with a relevant International Standard such as API STD 617, API STD 618, API STD 672 or any other recognised International Codes and Standards applicable to the specific type of compressor.

9.4 Turbines

9.4.1 Turbines are to comply with a relevant International Standard such as API STD 616 or any other recognised International Codes and Standards applicable to the specific type of turbine.

9.4.2 Safety requirements of turbines shall be in compliance with ISO 21789 or a similar recognised International Code or Standard.

9.5 Internal combustion engine units

9.5.1 Internal combustion engines are to comply with a relevant International Standard such as ISO 7967 series or any other recognised International Codes and Standards applicable to the specific type of engine. Combustion engines for installation in hazardous areas should be approved for their use and in general have safety requirements in accordance with provisions indicated in API RP 7C-11F, EN 1834-1 or a similar recognised International Code or Standard.

9.6 Lifting appliances

9.6.1 Lifting appliances and materials handling equipment such as cranes, runway beam monorails, mobile deck cranes, trolleys, padeyes, beam clamps, davits, etc. or other types of lifting and transporting devices are to be provided for the disassembly and reinstallation maintenance of all heavy equipment such as valves, pumps, gearboxes, engines and motors as applicable, including cases for equipment removal as a whole unit or for a change-out of the heavy internal parts as applicable. The design of lifting appliances shall be in accordance with the *Code for Lifting Appliances in a Marine Environment, July 2022*, EN 13852-1, EN 13852-3 or API Specification 2C, as applicable. Operation and maintenance of cranes shall meet the *Code for Lifting Appliances in a Marine Environment, July 2022*, API RP 2D, ISO 4309, ISO 12478-1, ISO 12482-1 and ISO 9927, as applicable.

9.6.2 Accesses to major equipment, vessels, pumps or valves are to be so designed as to permit use of mechanical handling/ lifting devices.

9.6.3 Removal routes to the platform crane pick up point at the laydown area for all major removable equipment should have adequate deck capacity for trolley loads. Pulling posts or other anchor points for pulling devices shall be designed in way of the removal route to aid with movement of trollies through the route.

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Section 1
Safety and communication systems

1.1 General requirements

1.1.1 This Section does not address hydrocarbon cryogenic processing, storage, import or export facilities.

1.1.2 Reference is to be made to guidance presented in *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for fire and gas alarm indication and control systems, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.3 Reference is to be made to guidance presented in *Pt 7, Ch 1, 3 Systems for broadcasting safety information* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for personnel warning systems, general alarms and public address systems, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.4 Reference is to be made to guidance presented in *Pt 7, Ch 1, 4 Emergency lighting* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for emergency lighting, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.5 Reference is to be made to guidance presented in *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for protection against gas ingress into safe areas, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.6 Reference is to be made to guidance presented in *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for protection against gas ingress into safe areas, is givenin *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.7 Reference is to be made to guidance presented in *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for Emergency shutdown (ESD) systems, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.8 Reference is to be made to guidance presented in *Pt 7, Ch 1, 8 Emergency release systems (ERS)* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. Additional guidance, specific to fixed offshore installations for ERS, is given in *Ch 8, 1 Safety and communication systems* of this Recommended Practice as applicable to a fixed offshore installation.

1.1.9 Reference is to be made to guidance presented in *Pt 7, Ch 1, 9 Riser systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* for riser systems states requirements for control and alarms of riser systems.

1.2 Documentation

1.2.1 The following documentation, as far as applicable to the installation, is to be submitted but further documents may be required:

(a) Fire and gas system design philosophy document.
(b) Fire and gas system ‘cause and effect’ diagrams, including actions on heating, ventilating and air conditioning systems.
(c) Layout drawing showing the positions of fire and gas detector heads, manually operated call points, control panels and repeaters, cable routes, and fire zones and their associated certification.
(d) Fire pump control, alarm, starting and inhibiting arrangements.

(e) For public address and general alarms, unit status indicators and emergency lighting.
(f) Communications philosophy document.
(g) Unit layout drawings showing location of fire zones, equipment and cable routes.
(h) Emergency lighting philosophy and layouts.
(i) ESD philosophy document.
(j) Safety analysis tables based on results of HAZOP studies/reports.
(k) Performance standards and criteria of the safety critical system.
(l) Fire-fighting system Process and Instrument Diagrams (P&IDs).
(m) Safety integrity level categorisation study for the instrument protective system.
(n) Alarm and trip schedules.

1.3 Safety and communications equipment

1.3.1 Reference is to be made to guidance presented for construction, detailed design, survey, inspection and testing of electrical and electronic equipment contained in *Pt 6, Ch 1 Control Engineering Systems* and *Pt 6, Ch 2 Electrical Engineering* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.3.2 Reference is to be made to guidance presented for construction, detailed design, survey, inspection and testing of pneumatic and hydraulic equipment contained in *Pt 5, Ch 1 General Requirements for Offshore Units*, *Pt 5, Ch 12 Piping Design Requirements* and *Pt 5, Ch 14 Machinery Piping Systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.3.3 Equipment used in safety and communication systems should be suitable for its intended purpose, and accordingly, whenever practicable, should be selected from the LR List of Type Approved Products. A copy of the procedure for the LR Type Approval System will be supplied on application. Alternative suitable certification/approvals for safety and communication equipment, to other International Codes and Standards, will be considered. For fire detection alarm systems, reference is to be made to guidance presented in *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*. For networked and programmable electronic systems, *see Pt 6, Ch 1, 1.2 Documentation required for design review* and *Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.3.4 Where equipment requires a controlled environment, an alternative means should be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see Pt 6, Ch 1, 1.3 Control, alarm and safety equipment* of the *Rules and Regulations for the Classification of Offshore Units, July 2022*.

1.3.5 Assessment of performance parameters such as accuracy, repeatability, etc. is to be in accordance with an acceptable National or International Standard.

1.4 Fire and gas alarm indication and control systems

1.4.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.4.2 The requirements and functional performance of fire and gas (F&G) systems are defined in other Sections of this document. This Section relates to the performance and installation of the detectors. This Section relates to fixed detectors only.

1.4.3 For the purposes of cabling and mounting, F&G detectors can be considered as instruments and the requirements of the previous Sections can be applied.

1.5 Flammable gas detection systems

1.5.1 Flammable gas detection is to be provided on facilities with hydrocarbon or hydrogen gases present. Consideration should be given to the location of such detectors related to the molecular weight of the gas to be measured, temperature and other environmental conditions.

1.5.2 Detectors may be Line of Sight (LoS) or point detectors depending on the area of coverage required, and will be defined on the F&G layout drawings. Voting of detectors are to be in accordance with the cause and effect diagrams.

1.6 Toxic and asphyxiant gas detection systems

1.6.1 Toxic gas detection may be required on process facilities handling sour gas, such as hydrogen sulphide. Where toxic gas detectors are required, consideration should be given to the location and height of the sensor to optimise the probability of detection. A requirement of toxic gas detection is the response time of the detector with respect to the time taken from initial

sensing of gas to the output reaching a given value, sometimes known as T60 or T90 times. It is an important function of a toxic gas detection system that it meets the response time requirements defined in the F&G philosophy.

1.6.2 Where enclosed spaces contain gases such as nitrogen and a release can cause an oxygen deficiency to personnel, fixed oxygen detectors are required. In such spaces an indication system should be located at each point of entry to alert personnel of the possibility of low oxygen levels inside. These systems should be designed as fail safe, i.e. lamps should be on to indicate a healthy state.

1.7 Fire and gas alarm indication and control systems for a normally unattended installation

1.7.1 A fire and gas detection indication and control panel is to be located at the centralised control station on the installation. A fire and gas repeater panel is to be provided at a location off the fixed installation, which is utilised to remotely monitor and provide control back to the fire and gas system of the normally unattended installation. The remote monitor and control location is to be attended at all times, by competent and responsible personnel, assigned for the remote monitoring and control of the normally unattended installation. The installation fire and gas detection indication and control panel and the remote repeater and control panel are to indicate the source of the fire on the normally unattended installation, in accordance with arranged fire zones by means of a visual signal. The remote repeater panel may indicate the general area of the fire zones affected.

1.7.2 The communications link between the normally unattended installation centralised control station fire and gas indication and control panel and the remote panel is to be secure and robust. Failure of the link between these two panels should initiate a suitable alarm indication on the normally unattended installation and at the remote monitor and control location. Should the loss of the link between these two panels occur for a determined prolonged duration, the potential initiation of an emergency shutdown of the normally unattended installation facilities should be considered, as automatically initiated logic. The duration of the loss of signal and initiation of the installation emergency shutdown functionality is to be assessed as part of the normally unattended installation safety philosophy.

1.7.3 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of installation fire pump(s) and the associated provision of fire water and/or water-foam solution systems can be assessed accordingly and potentially deemed as not required.

1.7.4 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of fixed active fire protection systems for dedicated installation facilities and/or enclosures – for example, machinery spaces protected by fixed water mist systems, gaseous fire suppressions systems, etc. – can be assessed accordingly and potentially deemed as not required.

1.7.5 Given the risks associated with a helideck fire, it is recommended that a helideck fixed fire-fighting system should be considered on a normally unattended installation. Ideally this helideck fixed fire-fighting system should be an integrated foam nozzle system/deck integrated fire-fighting system (DIFFS) but alternative helideck fixed fire-fighting systems can be considered. This system should be in accordance with the guidance given in Ch 17 of the IMO Fire Safety System (FSS) Code or Ch 5 of the UK Civil Aviation Authority (CAA) CAP 37. It is recommended that the helideck fixed fire-fighting system should be capable of automatic activation, on detection of a helideck fire. It should also be capable of manual activation at suitable locations near the helideck and remotely at the remote monitor and control location off the fixed installation.

1.7.6 The need for remote manual reset of any activated installation safety system, for example a closed ventilation fire damper, at the remote monitor and control location off a normally unattended installation, should be carefully considered. It should be ensured that any remote manual reset, avoiding the need for personnel to attend the installation, should not adversely reduce the integrity of an installation's safety system(s).

1.8 Fire and gas alarm indication and control systems for offshore electrical substations/transformer for offshore electrical power generation

1.8.1 If the facility is not engaged in the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, the requirement for gas detection, particularly flammable gas detection, can be assessed accordingly and potentially deemed as unnecessary.

1.9 Systems for broadcasting safety information

1.9.1 Reference is to be made to guidance in *Pt 7, Ch 1, 3 Systems for broadcasting safety information* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.10 Public address system

1.10.1 For the requirements of public address systems, reference is to be made to guidance presented in *Pt 7, Ch 1, 3.2 Public address system* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.10.2 The provision of public address systems on a normally unattended installation can be assessed accordingly and potentially deemed as not required. The potential exemption of a public address system on a normally unattended installation is dependent upon the provision of suitable processes, procedures and equipment to enable rapid communication between personnel attending the installation. For example, the provision of suitable two-way radios for personnel attending an installation, etc.

1.11 General emergency alarm systems

1.11.1 For the requirements of general emergency alarm systems, reference is to be made to guidance presented in *Pt 7, Ch 1, 3.3 General emergency alarm systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.12 Fire-extinguishing media release alarms

1.12.1 For the requirements of fire-extinguishing media release alarms, reference is to be made to guidance presented in *Pt 7, Ch 1, 3.4 Fire-extinguishing media release alarms* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.13 Escape route or low location lighting (LLL)

1.13.1 For the requirements of escape route or low location lighting (LLL), reference is to be made to guidance presented in *Pt 7, Ch 1, 3.5 Escape route or low location lighting (LLL)* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.14 Mud system level alarms

1.14.1 For the requirements of drilling mud system level alarms, reference is to be made to guidance presented in *Pt 7, Ch 1, 3.6 Mud system level alarms* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.15 Emergency lighting

1.15.1 For the requirements of emergency lighting equipment, reference is to be made to guidance presented in *Pt 7, Ch 1, 4 Emergency lighting* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.16 Protection against gas ingress into safe areas

1.16.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.16.2 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the provision of gas detection, particularly flammable gas detection, and gas ingress protection measures can be assessed accordingly and potentially deemed as not required.

1.17 Protection against gas escape in enclosed and semi-enclosed hazardous areas

1.17.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.17.2 If the facility is not engaged in processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the provision of gas detection, particularly flammable gas detection, and gas ingress protection measures can be assessed accordingly and potentially deemed as not required.

1.18 Emergency shutdown (ESD) systems

1.18.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.19 Electrical equipment

1.19.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 7.2 Electrical equipment* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.19.2 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the requirement for remaining operational equipment during a major accident event to be type permitted within a Zone 1 location, when installed in locations outwith any installation classified as a Zone 1 or Zone 2 hazardous area or space, can be assessed accordingly and potentially deemed as unnecessary.

1.20 Testing Emergency Shutdown (ESD) systems

1.20.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 7.3 Testing* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.21 Linked ESD systems

1.21.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 7.4 Linked ESD systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.22 ESD alarm indication and control systems for a normally unattended installation

1.22.1 An ESD indication and control panel is to be located at the centralised control station on the installation. An ESD repeater panel is to be provided at a location off the fixed installation, which is utilised to remotely monitor and provide control back to the ESD system of the normally unattended installation. The remote monitor and control location is to be attended at all times, by competent and responsible personnel, assigned for the remote monitoring and control of the normally unattended installation.

1.22.2 The communications link between the normally unattended installation centralised control station ESD indication and control panel and the remote panel is to be secure and robust. Failure of the link between these two panels should initiate suitable alarm indication on the normally unattended installation and at the remote monitor and control location. Should the loss of the link between these two panels occur for a determined prolonged duration, the potential initiation of an emergency shutdown of the normally unattended installation facilities should be considered, as automatically initiated logic. The duration of the loss of signal and initiation of the installation emergency shutdown functionality is to be assessed as part of the normally unattended installation safety philosophy.

1.22.3 The need for remote manual reset of any activated installation safety system, for example a closed emergency shutdown valve, at the remote monitor and control location off the fixed installation, should be carefully considered. It should be ensured that any remote manual reset, avoiding the need for personnel to attend the installation, should not adversely reduce the integrity of an installation's safety system(s).

1.23 Emergency release systems (ERS)

1.23.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 8 Emergency release systems (ERS)* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.24 Electrical

1.24.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 8.2 Electrical* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.25 Testing Emergency Release Systems (ERS)

1.25.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 8.3 Testing* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

1.26 Riser systems

1.26.1 Reference is to be made to guidance presented in *Pt 7, Ch 1, 9 Riser systems* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations.

Section 2
Hazardous areas and ventilation

2.1 Hazardous areas – General

2.1.1 Reference is to be made to guidance presented in *Pt 7, Ch 2 Hazardous Areas and Ventilation* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to hazardous areas.

2.2 Classification of hazardous areas

2.2.1 Reference is to be made to guidance presented in *Pt 7, Ch 2 Hazardous Areas and Ventilation* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to hazardous areas.

2.3 Hazardous areas – Drilling, workover and wirelining operations

2.3.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to hazardous area drilling, workover and wirelining operations classification.

2.4 Enclosed and semi-enclosed spaces with access to a hazardous area

2.4.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to enclosed and semi-enclosed spaces with access to a hazardous area.

2.5 Machinery in hazardous areas

2.5.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 5 Machinery in hazardous areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to machinery in hazardous areas.

2.6 Ventilation

2.6.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 6 Ventilation* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to ventilation.

2.6.2 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the provision of gas detection, particularly flammable gas detection, and gas ingress protection measures can be assessed accordingly and potentially deemed as not required.

2.7 Mechanical ventilation and HVAC

2.7.1 Design of the HVAC system shall meet the requirements of a recognised International Standard such as ISO 15138.

2.7.2 Non-hazardous enclosed spaces or those required to be operational under emergency conditions, such as control rooms or temporary refuges, should be maintained with an overpressure of at least 50 Pa in relation to any adjacent more hazardous areas or spaces. The non-hazardous area ventilation with positive pressurisation is to be designed to militate against potential gas ingress to the non-hazardous area so that where there is any doorway, hatch or other opening in the contiguous boundary, the ventilation should prevent the transmission of fluids from the more hazardous area or space to the less hazardous space.

2.7.3 Accommodation spaces should be provided with a HVAC system and maintained at a positive pressure in relation to the outside atmosphere.

2.7.4 Battery rooms should be provided with a HVAC system and maintained at a negative pressure in relation to non-hazardous adjacent spaces or rooms.

2.7.5 Supply air intakes should be located in external non-hazardous areas, at least 3 m from the boundary of any hazardous area; the separation between air intakes and outlets should be at least 4,5 m. The siting of inlets and outlets should be such as to avoid the possibility of cross-contamination.

2.8 Engines in hazardous areas

2.8.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 7 Engines in hazardous areas* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to engines in hazardous areas.

2.9 Electrical equipment for use in explosive gas atmospheres

2.9.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to electrical equipment for use in explosive gas atmospheres.

2.9.2 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the requirements for remaining operational equipment during a major accident event to be type permitted within a Zone 1 location, when installed in a location outwith any installation classified as a Zone 1 or Zone 2 hazardous area or space, can be assessed accordingly and potentially deemed as unnecessary.

2.10 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)

2.10.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to electrical equipment for use in explosive gas atmospheres.

2.11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes

2.11.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to electrical equipment for use in explosive gas atmospheres.

2.12 Requirements for units with space for storing paint

2.12.1 Reference is to be made to guidance presented in *Pt 7, Ch 2, 12 Requirements for units with space for storing paint* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to requirements for units with space for storing paint.

■ *Section 3* Fire safety

3.1 General requirements

3.1.1 Reference is to be made to guidance presented in *Pt 7, Ch 3, 1 General* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to general requirements.

3.1.2 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is an accommodation installation connected to or in proximity to such an installation, the provision of gas detection, particularly flammable gas detection, and gas ingress protection measures can be assessed accordingly and potentially deemed as not required.

3.1.3 Reference is to be made to guidance presented in *Pt 7, Ch 3, 2 Definitions* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to definitions.

3.1.4 Reference is to be made to guidance presented in *Pt 7, Ch 3, 3 Additional requirements for units with drilling and/or production and process plant or pipe-laying system* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to additional requirements for units with drilling and/or production and process plant.

3.1.5 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of installation fire pump(s) and the associated provision of fire water and/or water-foam solution systems can be assessed accordingly and potentially deemed as not required.

3.1.6 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of fixed active fire protection systems for dedicated installation facilities and/or enclosures – for example, machinery spaces protected by fixed water mist systems or gaseous fire suppressions systems, etc. – can be assessed accordingly and potentially deemed as not required.

3.1.7 For a normally unattended installation fitted with a helideck, it is recommended that a helideck fixed fire-fighting system should be considered. Ideally this helideck fixed fire-fighting system should be an integrated foam nozzle system/deck integrated fire-fighting system (DIFFS) but an alternative helideck fixed fire-fighting system can be considered. This system should be in accordance with the guidance given in Ch 17 of the IMO Fire Safety System (FSS) Code or Ch 5 of the UK Civil Aviation Authority (CAA) CAP 37. It is recommended that the helideck fixed fire-fighting system should be capable of automatic activation, on detection of a helideck fire. It should also be capable of manual activation at suitable locations near the helideck and remotely at the remote monitor and control location off the fixed installation.

3.1.8 The need for remote manual reset of any activated installation safety system, for example an activated fixed fire-fighting system, at a remote monitor and control location off a normally unattended installation, should be carefully considered. It should be ensured that any remote manual reset, avoiding the need for personnel to attend the installation, should not adversely reduce the integrity of an installation's fixed fire-fighting system.

3.2 Means of escape, evacuation and rescue

3.2.1 Reference is to be made to guidance presented in *Pt 7, Ch 3, 4 Means of escape, evacuation and rescue* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to means of escape, evacuation and rescue.

3.2.2 Normally attended installations are to be equipped with lifeboat(s) of a totally enclosed motor propelled survival craft type, of such capacity as will accommodate all persons on the installation. The number and installed locations of lifeboat(s) should take full consideration of potential survivability of the lifeboat(s) during an installation major accident event. Additionally, the number and installed locations of lifeboat(s) should take full consideration of potential loss of lifeboat(s) availability, due to loss of access during a major accident event and repair or significant maintenance work on a lifeboat.

3.2.3 Bridge-links for evacuation of installation personnel to a suitable place of safety, a suitable distance away from the installation, may be considered as an alternative to installation lifeboat(s). However, it must always be ensured that all installation personnel ultimately have access to lifeboat(s) on a bridge-linked installation, or walkways direct to shore.

3.2.4 For a facility engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or that is an accommodation installation connected to or in proximity to such an installation, the lifeboat(s) are to be fitted with a self-contained air support system. Additionally, lifeboat(s) are to be fitted with a water spray fire-protected system, designed to operate when the lifeboat is deployed in the sea.

3.2.5 Lifeboat(s) and launching arrangements are to be designed in accordance with the IMO Life-Saving Appliance (LSA) Code.

3.2.6 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of installation lifeboat(s) can be assessed accordingly and potentially deemed as not required.

3.2.7 All installations (normally attended installation and normally unattended installation) are to be equipped with life raft(s) of such capacity as will accommodate all persons on the installation. The number and installed locations of life raft(s) should take full consideration of potential survivability of the life raft storage and launching location during an installation major accident event. All life rafts are to be provided with launch arrangements that militate against the need for personnel to enter the sea (e.g. marine evacuation systems, davit launching arrangements, personnel descent devices for all life raft personnel, adjacent ladders/stairs to sea level access platforms). Scramble nets are not considered appropriate. Knotted ropes may be considered as an additional installation escape to sea facility but are not to be used as an alternative to the outlined escape to sea arrangements.

3.2.8 Life raft(s) and marine evacuation systems and davit launching arrangements to be designed in accordance with the IMO Life-Saving Appliance (LSA) Code.

3.2.9 If fast rescue facilities are available for the installation (suitable standby vessel facilities for either normally attended or normally unattended installations), a rescue boat is not required to be fitted on the fixed installation.

3.2.10 All other installation life-saving equipment is to be in compliance with the requirements of the *2009 MODU Code – Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26) Chapter 10 – Life-Saving Appliances and Equipment*.

3.2.11 Utilised safety equipment for installation evacuation or escape to sea and life-saving appliances, should be type approved. Whenever practicable they should be selected from the LR List of Type Approved Products.

3.3 Deckhouses and superstructures used for accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter'

3.3.1 Reference is to be made to guidance provided in *Pt 7, Ch 3, 5 Deckhouses and superstructures used for accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter'* of the *Rules and Regulations for the Classification of Offshore Units, July 2022* as applicable to fixed offshore installations with regards to deckhouses and superstructures used for accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter'.

3.3.2 Dependent upon the occupancy of personnel and the safety philosophy utilised on a normally unattended installation, the provision of a 'temporary refuge' or 'alternative/secondary refuge' can be assessed accordingly and potentially deemed as not required. However, it shall always be ensured that there is a defined safe location on the installation for all installation personnel to muster, prior to personnel evacuation or escaping from the installation.

3.3.3 If the facility is not engaged in the processing of hydrocarbons and/or storage of crude oil in bulk, the control of hydrocarbon pipelines or subsea wellheads, or utilised as part of a hydrocarbon pipeline system, or is .an accommodation unit connected to or in proximity to such an installation, the provision of gas detection, particularly flammable gas detection, and gas ingress protection measures can be assessed accordingly and potentially deemed as not required.

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